ARIZONA

DEPARTMENT OF

ENVIRONMENTAL

QUALITY

Evaluation of Activities
Occurring in Riparian Areas
1993

ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY
Evaluation of Activities Occurring
in Riparian Areas

Prepared by

Nonpoint Source Unit
Water Assessment Section

The Arizona Department of Environmental Quality shall preserve, protect and enhance the environment and public health, and shall be a leader in the development of public policy to maintain and improve the quality of Arizona's air, land and water resources.

EDWARD Z. FOX, DIRECTOR

FIFE SYMINGTON, GOVERNOR

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Executive Summary

In 1992 the Arizona legislature passed a bill (A.R.S. §45-101) which required the identification of a program to protect riparian areas in Arizona.

The legislation created a Governor appointed Riparian Area Advisory Committee consisting of representatives of many interests within Arizona. The bill also required the Arizona Department of Environmental Quality (ADEQ), Arizona Game and Fish Department (AGFD) and the Arizona Department of Water Resources (ADWR) to complete various studies regarding riparian areas. Once completed, all these studies are to be used by the Riparian Area Advisory Committee to prepare recommendations for proposed statutory provisions for a riparian area protection program in this state.

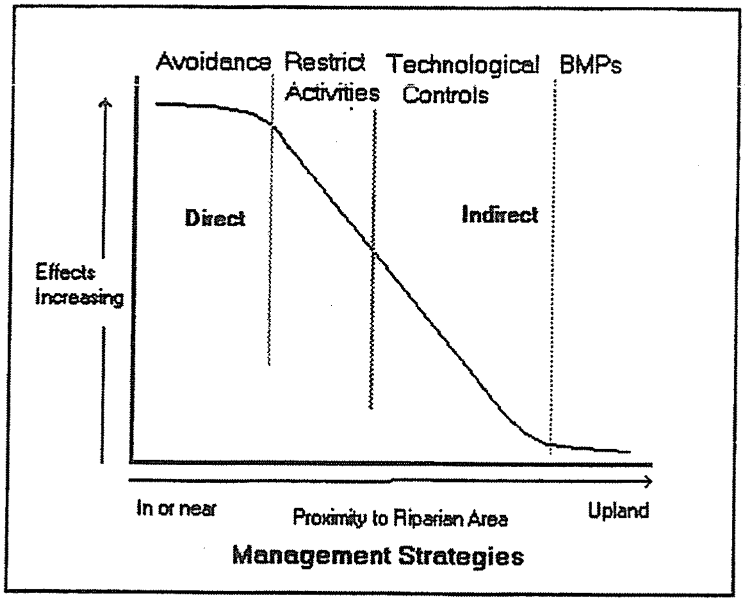
The Department of Environmental Quality was specifically required to evaluate twelve activities in Arizona relative to "...removing or depositing material, removing vegetation, or otherwise obstructing, altering or destroying riparian areas." This report was required by statute to be completed by October 1, 1993. Subsequent reports will be submitted by AGFD and ADWR by December 1, 1993.

The interaction of various activities and their effects on riparian areas is very complex and variable. The effects of activities on riparian areas vary in intensity, extent, and frequency, as well as in location and duration. While this complexity makes it difficult to completely evaluate the effects of all of these activities, it is possible to generalize the effects of each activity individually.

Water availability is the driving force in riparian areas and is particularly critical in an arid state such as Arizona. Any activity which disrupts the availability of water or disturbs streamflow and groundwater through modifications of the channel and/or floodplain is a concern for the effect it will have on the riparian area. There are certain activities that directly effect riparian vegetation. While it is possible for vegetation to recover, other concurrent effects may frustrate the process of reestablishment.

Activities often exhibit site preferences relative to the landscape. Some activities are intended to exploit a resource that is within or around streams and riparian areas or have a function that is directly linked to a stream channel flood plain or riparian area. Other activities may not be directly related to streams or floodplains in this way, but may have a preference for lowland sites which surround these areas. Other activities may have no such preference or may have a preference for upland areas. As activities move from the stream channel toward upland areas the effects associated with them change from predominantly direct (interruption of flow, channel modification, vegetation removal) to predominantly indirect (upland drainage modification, introduction of pollutants, soil surface disruption).

The management of these activities will vary depending on the nature of the effect and the location of the activity on the landscape. Activities directly in the channel which effect water availability, channel geometry or vegetation could be managed through proper siting to avoid or minimize these disruptions.



Activities that are located out of riparian areas but in the uplands could be managed by minimizing indirect effects to either the water quality or the physical nature of the stream. Appropriate management in these cases will be realized by modification in the management and operation of the activities or by utilizing technological controls such as sediment controls and water treatment for discharges.

Potential management strategies to protect riparian areas include avoidance, restriction of activities, technological controls, and BMPs. For those activities having the greatest number and intensity of effects directly in or near riparian areas, avoidance of riparian areas may be the most effective management tool. Restrictions of activities may be used for those activities which may directly affect riparian areas depending on the "value" of the riparian area. Reduction of indirect effects using technological or other management tools may used for activities which are farther away from riparian areas. For those activities which occur primarily on the upland the use of BMPs can help reduce the indirect effects. Of course, BMPs, technological controls, restriction of activity and avoidance of riparian areas can be used by all activities to protect riparian areas.

Arizona Department of Environmental Quality
Evaluation of Activities Occurring in Riparian Areas

Introduction

This report evaluates selected activities occurring in riparian areas in the State of Arizona. In 1992, the Legislature of the State of Arizona assigned the following duties to the Arizona Department of Environmental Quality (ADEQ):

> ...identify activities, operations and uses that occur on land in riparian areas of federal, state and private property in this state that involve removing or depositing material, removing vegetation or otherwise obstructing, altering or destroying riparian areas. The department shall evaluate at least the following activities:
>
> 1. Timber harvesting
> 2. Agricultural land clearing
> 3. Recreational use and development
> 4. Commercial, industrial and residential development
> 5. Road and bridge construction
> 6. Dam and reservoir construction and operation
> 7. Channelization and bank stabilization
> 8. Sand and gravel extraction
> 9. Wetland drainage
> 10. Grazing
> 11. Landfills and sewage treatment facilities
> 12. Mining and metallurgical operations
>
> (A.R.S. §45-101.6.A.)

Riparian areas are important for both ecological and economic reasons, a fact that is amplified by the passage of the riparian legislation (A.R.S. §45-101 et. seq.). They are unique parts of the ecosystem that are limited in size and number. Many human activities both rely on and impact riparian area resources.

This report is intended to evaluate the activities for their impacts on riparian areas. It is not intended to be an in-depth, scientific reference. It is presented as background information for individuals involved with decisions on protecting riparian areas. It was written within the limitations of information availability, access to data and the existing levels of scientific references. Professional judgement has been used in areas where uncertainty or conflicting interpretations exist.

This report is the first of three reports related to riparian resources. Locations of riparian areas are being mapped by the Arizona Game and Fish Department's (AGFD) riparian area inventory and classification process. Identification of their functions and values will be included (A.R.S. §45-101.5). The Arizona Department of Water Resources (ADWR) will evaluate the impact of surface water diversions and groundwater pumping on riparian areas (A.R.S. §45-101.3). All three reports will provide the Riparian Area Advisory Committee with background information to use in making recommendations for a riparian area protection program.

Definitions

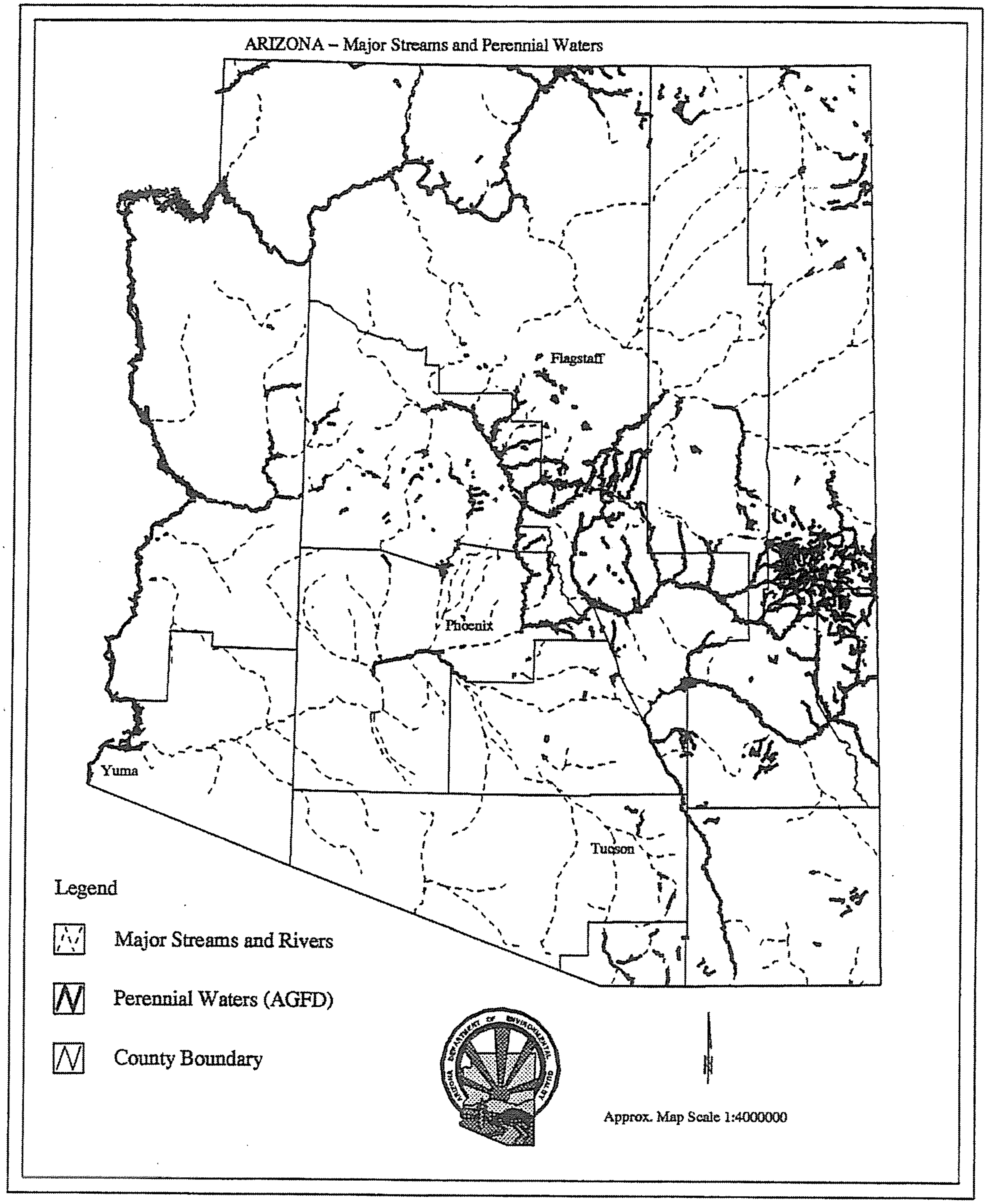
In this report, **evaluate** means to identify effects, both direct and indirect, of activities on riparian areas. The effects identified are on the major functions and ecological components of these areas. Activities were evaluated in relation to the removal or deposition of material, removal of vegetation, or other obstruction, alteration or destruction of riparian areas as suggested in A.R.S. §45-101.6.A.

The following definition of **riparian area** has been used in the evaluation process:

> "Riparian Area" means a geographically delineated area with distinct resource values, that is characterized by deep-rooted plant species that depend on having roots in the water table or its capillary zone and that occurs within or adjacent to a natural perennial or intermittent stream channel or within or adjacent to a lake, pond or marsh bed maintained primarily by natural water sources. Riparian area does not include areas in or adjacent to ephemeral stream channels, artificially created stockponds, man-made storage reservoirs constructed primarily for conservation or regulatory storage, municipal and industrial ponds or man-made water transportation, distribution, off-stream storage and collections systems. (A.R.S. §45-101.7)

The United States Geological Survey (USGS) describes stream classifications for surface water hydrology. A **perennial** stream is one which flows continuously. An **intermittent** or **seasonal** stream is one which flows only at certain times of the year. This type of stream flows when it receives water from springs or from some surface source such as melting snow. **Figure 1** is a map of perennial and intermittent rivers and streams in Arizona.

Figure 1. Arizona's major streams and perennial waters.



Methodology

The method used for this evaluation consisted of four steps. The steps are described as follows.

Step 1. Identify activities that could effect riparian areas. The riparian legislation (A.R.S. §45-101) listed the activities to be evaluated and was considered complete. The only change was the splitting of the landfills and sewage treatment facilities activity into two activities, and sewage treatment was changed to wastewater treatment facilities.

Step 2. Verify that activities occur in and around potential riparian areas. Utilizing figure 1, it was determined that all the activities occur or potentially occur in or near perennial or intermittent streams in Arizona. This is not to imply that Figure 1 is a depiction of riparian areas. This was the best source of information available to determine riparian area potential.

Step 3. Evaluate each activity relative to potential effects, direct and indirect, based on reviewing published data and communication with land managers. Each activity was evaluated based on the worst case scenario. Each activity was evaluated relative to management practices that could be used to prevent, reduce, or mitigate effects.

Step 4. Summarization of the analysis of activities and effects was compiled so that activities can be compared with each other. The summary provides a comprehensive and succinct presentation of the complex interaction between the various activities and their effects on riparian areas.

Riparian Area Ecology

Riparian areas are linear corridors in which water and sediments are transported (Brinson et al. 1981). The areal extent, diversity and density of vegetation are dependent on the interaction of environmental factors, including: climate, elevation, hydrology, geology, and geomorphology.

Role of disturbance

Natural disturbances such as flooding, inundation, scouring and drought are important in the establishment, development and maintenance of riparian areas (Szaro 1989, Stromberg et al. 1991). In the spring, due to the snowmelt in high elevations, streamflows overtop their banks and bring water and sediments to the adjacent floodplain. The timing of seed dispersal with these high flows is essential to provide optimum conditions for seedling establishment. The high flows may have enough force to scour currently established vegetation. The open areas created allow more sunlight, a condition essential for seedling establishment. How a riparian area will respond to a disturbance is difficult to predict due to the complexity and dynamic nature of these areas.

Many human activities also disturb riparian areas. Activities may clear vegetation (scouring), remove water (drought), or change the channel geometry (channel migration) which disturb riparian areas. These disturbances, natural and human-caused, directly effect riparian areas. Other disturbances such as removing water in a stream will indirectly affect riparian areas. This causes riparian vegetation to decline or die due to the lack of water. The reduction of shading usually provided by streamside plants will cause water temperatures to increase.

Riparian vegetation have evolved adaptive characteristics to make them successful to disturbance regimes. The ability to recover after a disturbance is intricately tied to how the environmental factors necessary for establishment and maintenance of vegetation are altered.

Functions of riparian areas

The importance of riparian areas is connected to the functions they perform (**Table 1**). Riparian areas are valuable for wildlife habitat by the fact that 75% or more of Arizona's wildlife species depend on healthy riparian areas during some portion of their life cycle (GRHTF 1990). Alluvial soils (sand, gravel and silt) in riparian areas permit infiltration of water to subsurface aquifers thus recharging groundwater supplies. The quality of water is improved by riparian vegetation trapping sediments that are in the streamflow or runoff from upland areas. Erosive forces of water are dissipated when channel geometry is sinuous (curves and bends) and meandering. Riparian areas also coexist with valuable resources such as sand and gravel and recreation activities.

Disturbances caused naturally and by human activities effect riparian areas by inhibiting, enhancing or eliminating these functions. The effect various activities have to disturbing these functions were evaluated in this report.

Table 1. Functions and values of riparian areas.

FUNCTIONS AND VALUES OF RIPARIAN AREAS

Biotic Functions	Hydrologic Functions
Provide wildlife habitat	Groundwater discharge
Wildlife diversity	Groundwater recharge
Aquatic diversity	Channel to floodplain subsurface flow
Migration corridors	Temporary storage of flood waters
Vegetation filter between upland and aquatic systems	Flood control/dissipation of erosive forces
Microclimate modification - cooler temperatures	Reduction of peak flows
Critical habitat for Threatened & Endangered species	
Air pollution removal	
Recreation areas	
Water Quality Functions	**Channel Geometry (form) Functions**
Nutrient retention/uptake	Dissipation of erosive forces (energy dissipation)
Pollutant sequestering	Stabilization of bank materials
Physical adsorption (to plants and sediments)	Sediment retention (aggradation)
Chemical precipitation of metals	Sediment transport (degradation)
Biochemical breakdown or uptake	
Sediment retention (aggradation)	

Human values

Mineral resources	Water resource (quantity and quality)
Commercial products	Recreation & aesthetics (natural beauty)
Transportation corridor	Archeological & cultural resources
Food sources/production	Educational & research resource

Sources: Anderson, undated; Manci 1985, Johnson 1985, Arizona State Parks 1988, Kusler 1985, Hickin 1984, Peterjohn and Correll 1984, Pinay and Decamps 1988, Turner 1989, and Naiman et al. 1988, Cooper et al. 1990; Minckley and Brown, 1982; Kusler, 1985(a), Kusler, 1985(b); Ohmart and Anderson, 1986.

General History

Arizona has grown in population size in the last 150 years. Riparian areas have provided many of the resources to support this growth. This growth has stressed, and caused a reduction in the number of areas that support and maintain functioning riparian ecosystems (Dobyns 1981, Swift 1984). The generalized historical pattern is illustrated in **Figure 2.**

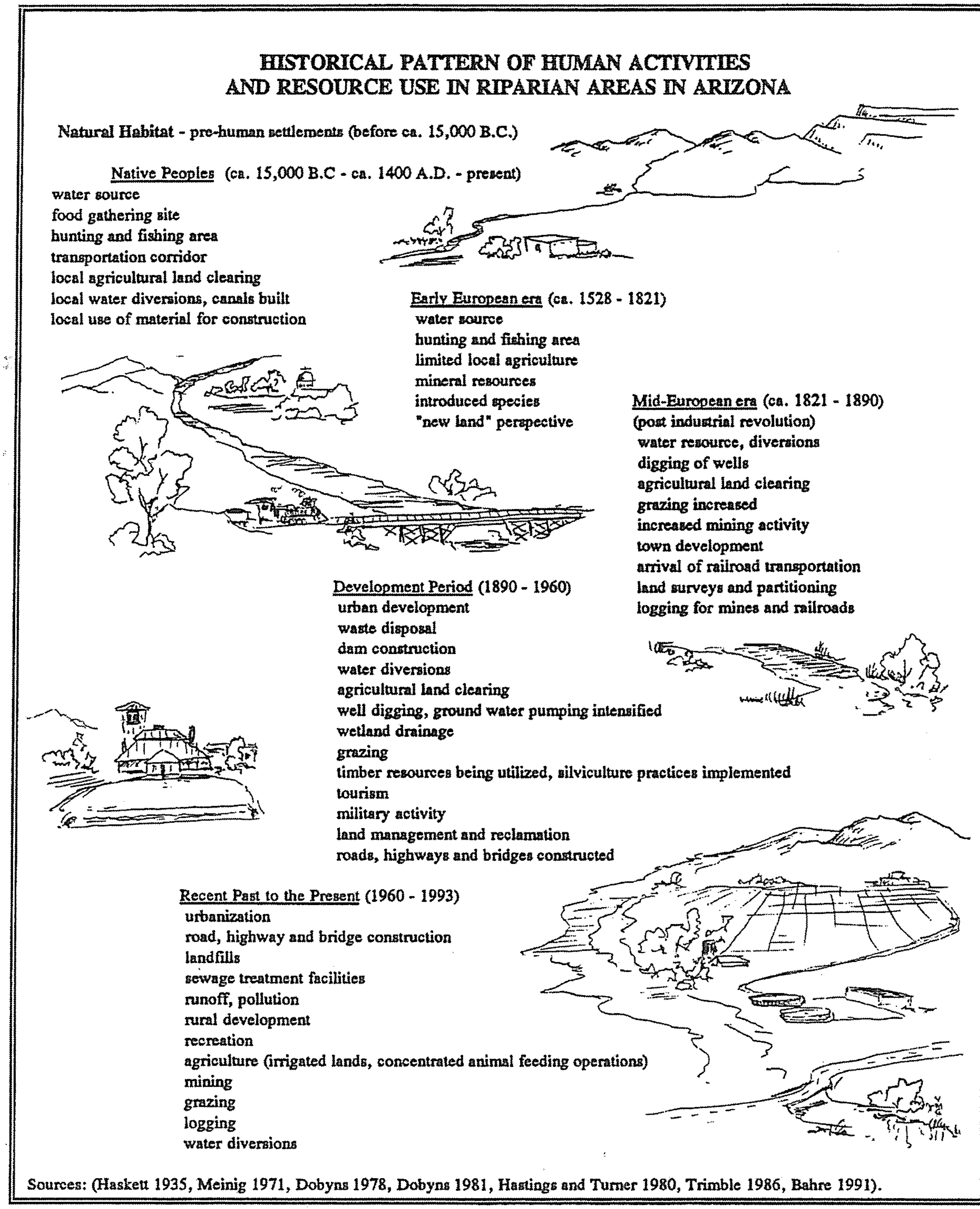
Based on the historical sequence of activities in riparian areas, the following is presented as a generalized chronological summary.

The earliest Native Americans to exploit or impact riparian areas were the Hohokam in central Arizona and the Anasazi in northern Arizona. Trails followed river valleys for ease of passage and access to water, food and game animals. With advances in plant cultivation, clearing of land for agriculture took place in riparian areas. Irrigation was possible on the rich soils with the construction of brush and rock diversion dams. Settlements grew as populations increased over time.

More recently, a similar sequence occurred. Early Spanish and American explorers followed waterways. Hunters and trappers sought beaver along the banks of the rivers and streams. Farmers utilized ancient canals for irrigation. A need for a more dependable supply of water developed as farm lands expanded. Larger dams were constructed to provide the water for their needs. With the dependable water and food supply, populations increased.

Other activities also are associated with larger populations. Cities and towns have expanded onto what was once farmlands. With these centers of population, sites for landfills and sewage treatment facilities are needed. These are often placed for convenience in the lowland riparian areas. The widespread use of automobiles increased the need for roads and bridges. Increases in leisure time has led to increased pressure for recreational use and development of facilities. Individual activities and their effect on riparian areas are presented in the following sections.

Figure 2. Historical pattern of human activities and resource use in riparian areas in Arizona.



Activities

The following section provides an evaluation of each of the activities previously identified. These activities, in the order presented, include:

- Timber harvesting
- Agricultural land clearing
- Recreational use and development
- Commercial, industrial and residential development
- Road and bridge construction
- Dam and reservoir construction and operation
- Channelization and bank stabilization
- Sand and gravel extraction
- Wetland drainage
- Grazing
- Landfill facilities
- Wastewater treatment facilities
- Mining and metallurgical operations

Each activity is described and the potential effects, direct and indirect, on riparian areas and management practices to mitigate the effects are identified.

For purposes of this analysis, an activity has a direct effect when some attribute of the activity creates a disturbance to the riparian area or the upland area which influences riparian vegetation, water quantity, channel and floodplain features, and water quality. Indirect effects occur in response to direct effects.

Direct and indirect effects as well as management practices are presented in tables within each activity description. A summarization of the direct effects and management practices is provided in the conclusion section.

Timber Harvesting

Description

Humans have used the natural resources of forests for centuries. In this respect, the forests of Arizona are no exception. Carbon dating of wood products from Anasazi settlements establish that forests were being harvested as early as 1000 years ago. In the 1800's, miners used timber for mine shaft or tunnel shoring. Wood was used for fuel to process ore. Wood harvested from Arizona's forests was an essential part of the development of the railroads. It was used for fuel and railroad ties. For a time, riverboats relied on cottonwood and mesquite wood harvested from the banks of the Colorado River for fuel. Early settlements were constructed primarily of wood. Wood products helped economic development and trade.

More than one quarter of the land in Arizona is forested. Ownership of these forested lands is divided with 43% on National Forest Lands, 16% on other public lands, and 41% on private lands. The largest portion of the private ownership is on Native American lands. The two major categories of forests are timberland and woodland. Timberland are wood products traditionally used for construction such as Ponderosa pine and Douglas-fir. Woodland trees such as pinyon pine and juniper are typically not used for wood products but are an important source of fuelwood. Timberland accounts for approximately 22% of the total 19.9 million forested acres in Arizona. Woodlands represent the remaining 78% of the total. The woodland figure includes large areas of pinyon-juniper (67%), juniper (16%), mesquite (9%), oak (8%) and other woodlands (1%) (Conner, et.al. 1990). The "other woodlands" category includes riparian area woodlands such as cottonwood-willow or mixed deciduous, broadleaf forests.

Riparian tree species range from the high elevation area pines, ash and cottonwood to low desert species such as ironwood, palo verde and mesquite. Oaks, sycamores and willows are found in mid-elevation riparian woodlands. The largest expanses of coniferous forests including pine, spruce, and fir occur at higher elevations of the State. These forests are found primarily on National Forest lands, National Park lands and some State trust lands.

The headwaters of many of the State's perennial streams originate within forested regions in high elevations. These high elevation forested watersheds collect snow and rainfall which provides much of the water for downstream riparian areas. The harvest and management of mid-elevation pinyon-juniper woodlands is often associated with cattle grazing. Trees are cleared to improve rangeland and promote the growth of desirable grasses.

Mesquite and juniper fire-wood is cut by both commercial and for private harvesters. To improve the conveyance capacity of flows in the channel salt cedar has periodically been removed from sections of the Salt and Gila Rivers.

Effects

Timber harvesting activities most often occurs in uplands areas. Riparian woodland trees are typically not commodity resources. Access road construction and operation of equipment are associated with timber harvesting activities which can affect riparian areas. The intensity of effects is related to: 1) the activity's proximity to a perennial or intermittent stream, 2) the number and location of roads built and their maintenance, 3) the number of trees removed from an area, 4) the timing of harvest, 5) the methods of harvesting used, and 6) post harvest management.

Timber harvesting effects vary from site to site because of variations in site conditions. **Table 2** presents the effects timber harvesting activities have in riparian areas of the State.

Timber harvesting activities disturb the soil due to road construction, movement of vehicles and machinery, vegetation removal and the placement of skid trails. The removal of trees directly affects understory vegetation and wildlife habitat. Sheet flows and flashy flooding can occur on cut forest lands. Riparian areas are affected by runoff and erosion when harvesting occurs nearby. Of the various water pollutants, sediment is the greatest single cause of water quality decline (EPA, 1973). Increased runoff from cleared areas and road construction can increase erosion, sedimentation and turbidity hence degrading the aquatic habitat negatively affecting insects, amphibians, and fish.

Clear cutting of trees results in soil disturbances, loss of herbaceous vegetation, and the spread of undesirable plant species. The effects of increased runoff and erosion can be decreased if buffer strips of vegetation are in place. Clear cutting can increase the chances for debris flows, increase runoff, as well as decreasing water quality. Large precipitation events may intensify the effects of clear cut areas. Land slides can occur in areas cut and filled for access road construction. Erosion control requires strict attention to the method of tree removal, the period between harvest, and the practices used in reestablishment of the forest (EPA, 1973).

Streamside habitats are affected by the removal of shade trees. Stream temperatures increase and the dissolved oxygen content in the water will decrease. The presence of suspended solids, additional nutrients, increased water temperatures, changes in pH and oxygen content in the stream can be extremely detrimental to fish and other aquatic wildlife.

Fire suppression practices have allowed a build up of fuel on the forest floor. Wildfires burn at higher temperatures and do more damage than fires that burn small quantities of fuel close to the ground. Appropriately located and implemented prescribed burns are beneficial to riparian areas. They remove fuel and burn at lower temperatures. When these fires reach riparian areas they are not as intense. There are other fire effects which are determined by soil characteristics and the shape of the land area burned. Steep slopes with loose soils will cause greater sedimentation of riparian areas than level areas. Other indirect fire issues include smoke reduction, fire break construction and runoff of fire retardants into streams.

Reforestation after timber harvesting can reduce soil erosion, and increase water infiltration.

Management

Management to protect riparian areas from the effects of timber harvesting and associated activities can result in better conditions over time (**Table 3**).

Table 2. Effects of timber harvesting activities in riparian areas.

EFFECTS ASSOCIATED WITH TIMBER HARVESTING ACTIVITIES	
DIRECT	**INDIRECT**
Removal of upland vegetation	Increase sediments Degrade aquatic habitat Increase runoff, erosion and water yields Change stream geometry Higher peak discharges
Operational procedures Harvesting equipment used Contamination - slash Access roads Log landings Loading decks (areas where logs are loaded onto trucks) Skid trails Fire breaks	Increase erosion runoff Increase soil compaction Increase soil disturbance
Removal of vegetation along streamside	Habitat alteration Increase water temperature Decrease oxygen content in water Increase pH of water (more acid)
Increase contaminants pesticides herbicides	Degrade aquatic habitat
Fuel build-up	Fire potential
Reforestation - tree planting	Increase upland habitat Decrease erosion runoff Increase nutrients to stream
Increase runoff, erosion, water yield	Increase sediments in channel Decrease aquatic habitat

Sources: USEPA, 1993; ADEQ, 1988; Brown and Krygier, 1971; Olson and Böhm, 1992; Malanchuk and Turner, 1987.

Upland woodland management is different from riparian woodland management. Generally, land management agencies in Arizona limit or restrict harvesting in riparian areas. These agencies have procedures and practices in place that, if followed, reduce the intensity of effects and the resultant environmental problems.

The use of existing management practices needs to be critically evaluated to minimize effects of timber harvesting activities upon riparian areas. Practices that must be appropriately implemented are skid trails, slash treatments, prescribed fires, reforestation, growth promotion, soil, disease, and insect protection. Additional practices used are selective harvesting, avoidance of critical habitat, and retention of buffer strips along all drainages.

Management opportunities exist to implement those practices. The use of these protective measures varies depending on the degree of concern shown by the individual contractors and timber sale managers. Evaluation of current timber harvesting practices reveals a greater awareness of the fragility and importance of riparian areas in overall ecosystem management. This awareness is apparent in statements of concern and the development of action plans that have been presented by the U.S. Forest Service and the Bureau of Land Management.

The agencies' management plans address the issue of improving riparian habitats under their respective jurisdictions (McCleese 1991, USDI, Bureau of Land Management, 1990). Riparian area protection is included in planning.

Table 3. Protective management practices for timber harvesting activities.

RIPARIAN AREAS PROTECTIVE MANAGEMENT PRACTICES for TIMBER HARVESTING ACTIVITIES
• Buffer zones - uncut areas adjacent to stream
• Riparian Area avoidance
• Selective harvesting
• Longer rotations between reharvesting
• Slash and debris (residue management)
• Log removal methods - Helicopter
• Vegetation manipulation - prescribed burning, replanting
• Prohibition of harvesting and road construction on steep slopes
• Erosion control and slope protection for roads and skid trails
• Control of sidecast materials
Sources: USEPA, 1993; Logan and Clinch, 1991; Larse, 1971

Agricultural Land Clearing

Description

The presence of rich, deep, alluvial soils, and a fairly reliable, year-round supply of water made stream and riverside areas ideal for the earliest people to establish cropland and irrigation systems. The construction of canals and a water diversion system in the Salt River Valley allowed the Hohokam people to open adjacent lands to farming. Modern dam construction has minimized the threat of flood flows allowing irrigated agriculture to expand onto middle and lower flood terraces. Federal regulations such as the Swampbuster Act actively promoted the conversion of riparian lands to farm and agricultural use.

Large scale clearing and leveling of lowland sites took place for mechanized, single crop agriculture. Large expanses of lowland areas were preferred for their soil conditions and for the ease of plowing and furrowing fields on relatively level lands for irrigation.

The majority of riparian area lands cleared for agriculture occurred in the upper portion of the floodplain within the last 100 years. Large expanses of riparian vegetation, particularly mesquite bosques, were cleared. Along the Santa Cruz River and the Verde River, riparian vegetation was cleared for pastures or fruit orchards. This was true along wide and meandering lower elevation rivers such as the Colorado River, Gila River, Santa Cruz River, Salt River and parts of the San Pedro River. There are few examples where agriculture occurs in or near the active, low flow channel because these areas are susceptible to flooding even after relatively small rainfalls. In the case of extremely high rainfall and runoff events, flooding of the middle and upper terraces may occur.

The need for water to irrigate crops has been the catalyst in the demand for construction of water diversion projects and well drilling. Agricultural development spread as water resources and newer technology became available. Historically, agriculture has used the largest quantities of water of any activity in the State. Surface waters were diverted by the Salt River Project in the Nation's first major reclamation project. The Central Arizona Project (CAP) was originally conceived as a way to provide more water to farmers in central Arizona.

Effects

There are two effects that agricultural land clearing have had on riparian areas. One effect is the clearing and preparation of land for agriculture and the second is agricultural activities such as irrigation of crops, application of herbicides, etc **(Table 4)**.

Agricultural land clearing has had a strong historic influence on riparian areas. Land clearing affects riparian areas directly by the removal of vegetation, disturbance and change in the soil, and by a change in the pattern of water dispersal and movement across the landscape. Leveling of the land increases soil disturbance and erosion. Federal regulations such as Section 404 of the Clean Water Act have restrictions to prevent degradation of water quality by activities such as land clearing.

Surface water diversions and groundwater pumping for irrigation have affected riparian areas. In some instances, the water table can become too high, causing a need to drain the land by pumping in order to avoid oversaturation at the root zone of plants (Yuma Valley). Prior to the development of the CAP, the principle water source for irrigation, outside of established irrigation districts, was groundwater. This pumping of ground water has had significant impacts on riparian areas by lowering the water table beyond the depth of plants roots results in the plants' eventual death. The lowered water table also can lead to a loss of surface water flows which completely removes the aquatic part of the riparian system.

Water removal by diversion for irrigation purposes has affected riparian areas in the State. The overall effect is sometimes reduced by agricultural return flows to downstream riparian areas. However, with these return flows, water quality becomes an issue because of increases in suspended solids, salt content and chemical contaminants from fertilizers or pesticide applications.

Table 4. The effects of agricultural land clearing in riparian areas in Arizona.

EFFECTS ASSOCIATED WITH AGRICULTURAL LAND CLEARING	
DIRECT	**INDIRECT**
Remove riparian vegetation	Habitat alteration Increase in water temperature Decrease in oxygen content in water Increase pH of water (more acid) Decrease in aquatic habitat Decrease in bank stabilization Increase in erosion
Remove water surface water diversions groundwater pumping	Decline/death of riparian vegetation Water table lowered
Level site/soil disturbance	Increase soil erosion Increase sediments in channel Destabilize bank material
Sediments, fertilizers, herbicides, pesticides from agriculture return flows	Increase aquatic plant productivity Decrease in oxygen content in water Adverse conditions for aquatic inhabitants Increase sediments in channel Decrease water quality
Remove upland vegetation	

Sources: USEPA, 1993; Peterjohn and Correll, 1984; Cooper et al., 1987; Lowrance et al., 1984; Omernik et al., 1981.

Agriculture return flows are exempted discharges under Section 402 of the Clean Water Act. The report being prepared by the Arizona Department of Water Resources will address the effects of surface water diversions and groundwater pumping more thoroughly.

Pesticide or fertilizer applications throughout an agricultural area may influence the health of riparian ecosystems. These effects may take the form of increased riparian vegetation responding to an increase of nutrients. Another effect may be the loss of beneficial members of the food chain that are killed by pesticides.

ADEQ, in its 1992 Water Quality Assessment, stated that agriculture is the predominant source of contamination in streams, affecting 1,563 of the 4,461 miles assessed in Arizona. Agriculture practices were stated to have contributed to accelerated erosion and high turbidity. However, this report included the activities of rangeland grazing, irrigated crop production and animal holding/management areas in assessing the total miles of streams impacted by agriculture.

Lowering of the water table, over saturated soils, concentration of salts in the soil, and loss of soil by erosion, are problems associated with agricultural land management that affect adjacent riparian areas.

Management

The most desirable locations for agriculture have been utilized. Currently, extensive clearing of new land is not a major activity. Future agricultural land clearing will be limited including lands in riparian areas, particularly within Active Management Areas (AMAs) as administered by the Department of Water Resources under the Groundwater Management Act of 1980. AMA plans have limited the development of new agricultural lands, slated to be cleared, due to the lack of available water. In some cases, lands will be retired from agriculture and no new acreage will be developed. There are some legislated exceptions allowing new development.

The limited expansion of agricultural land clearing also can be attributed to the price of farming in general, market values of crops, land costs, environmental concerns and the cost and availability of water. In some areas, such as on Native American lands, the prospect of water from the CAP may present an opportunity to expand agricultural lands. More activity is likely if pending water rights settlements and adjudications are favorable to Native American interests.

Management practices and methods designed to prevent erosion and promote soil conservation, decrease the chances of undesirable sedimentation. Methods to minimize contamination have also been developed. Careful stewardship of agricultural lands in the watershed reduces the effects of agriculture (**Table 5**).

Recent high water flooding events in Arizona have heightened the demand for construction of more dams or protective features such as levees or dikes. However, the cost to protect land from flood flows, either by levees or some other method, is prohibitive in some areas. Channelization has often been recommended as a way to protect the agricultural lands that were once part of the river's dynamic riparian ecosystem. This has been proposed for the Gila River downstream of the Painted Rocks Dam at the cost of $33 million. The effects of channel modifications may be more detrimental than the original land clearing.

Table 5. Protective management practices for agricultural land clearing activities.

RIPARIAN AREAS PROTECTIVE MANAGEMENT PRACTICES for AGRICULTURAL LAND CLEARING ACTIVITIES
• Prohibit clearing of riparian areas
• Establish or maintain filter strips of riparian vegetation
• Minimize areas cleared
• Minimize fertilizer and pesticide applications
• Provide runoff and return flow control and retention
• Control water usage through Active Management Areas (AMAs)
Sources: USEPA, 1993; ADEQ, 1993; Peterjohn and Correll, 1984; Cooper et al., 1987; Lowrance et al., 1984.

Recreation

Description

Arizona offers diverse recreational opportunities. There are very few sites in the state of Arizona that are not suitable for people who want a recreational experience. The effects that recreation use and development have on riparian areas are related to accessibility, number of people, and type of recreation.

Riparian areas are heavily utilized because of the attractive nature of water features. The presence of water and the cooling shade of trees mixed with grasses, shrubs and herbaceous understory make riparian areas very appealing.

The State's varied climate regions, together with the access provided by roads and trails allows year-round recreation. Recreation occurs on both private and public lands. National Forest lands, State lands, or National Park lands and Bureau of Land Management lands are all used for recreation.

Accessibility to recreation facilities and sites provide an opportunity for increased usage of some areas. Less accessible sites are less frequently visited and often do not provide the whole spectrum of amenities such as restrooms and picnic tables. Increasing interest in outdoor activities has led to further development of facilities and services to meet the higher demands at the more accessible sites.

Recreation is extremely variable and various forms of activities in riparian areas are available. Recreational use and development have been either concentrated or dispersed. Passive recreation such as sight-seeing has little affect on riparian areas. Active recreation such as recreational vehicle use, hiking and horseback riding can be found directly in riparian areas and can have greater effects.

Effects

Availability of facilities increases the utilization of an area. The presence of people may affect riparian areas by removing or damaging vegetation and disrupting wildlife, however, these effects are generally not permanent. The riparian area is not eliminated but effects can be cumulative. The effects of recreational use and development are presented in **Table 6.**

The cumulative effects of user activities in riparian areas is related to the: 1) number of people, 2) proximity to a perennial or intermittent stream, and 3) length of time people are present at the site. Local overuse affects ecological relationships at the site as well as those in the immediate surrounding area. In addition, the behavior of the individual recreationist plays an important role in the effect on riparian areas. This variable is difficult to evaluate since the intensity of impacts is also related to the attitudes and values of the individual users.

The direct effects recreation has on riparian areas have been on the three major components of riparian areas: vegetation, channel and water.

Table 6. Effects of recreational use and development.

EFFECTS ASSOCIATED WITH RECREATIONAL USE AND DEVELOPMENT	
DIRECT	**INDIRECT**
Removal of riparian vegetation	Increase in sediment Increase in water temperature Elimination of seedlings
Decrease in wildlife	Decrease in biodiversity
Increase soil compaction	Reduced water infiltration Reduction in organic ground cover
Increase in contaminants sediments nutrients	Deposition in channel Degrades aquatic habitat Increase in pH (more acid) Increase in bacteria Decrease dissolved oxygen in water
Alter channel material (stream crossing effects)	Degrade stream bed / erosion Decrease bank stability Increase soil compaction Destabilize bank material Increase sediments

Sources: ADEQ, 1988; ASP, 1989; Johnson and Carothers, 1982; Turner, 1983; Menasco, 1990.

Local damage or removal of young trees and other vegetation, disruption of wildlife, soil compaction or disturbance and water pollution can result from recreation.

Development of facilities alters the natural site conditions by clearing vegetation and developing some protective measures on the banks or in the channel. Streamflow volume and velocities are important in determining which recreation activities are present. Different activities such as swimming, fishing and boating utilize different streamflows. Quality of recreation increases with flow to a point and then decreases for further increases in flow (Brown et al. 1991)

In the watershed or along streams, common litter and debris are thrown into streams resulting in poor water quality and aesthetic conditions. Loss of vegetation, shade removal, and the removal of large woody material cause water temperature to increase resulting in a lowering of dissolved oxygen. Many aquatic species, especially fish, are affected by those changes.

Water quality can be affected by recreation. Human waste from unmanaged sites or improperly designed facilities at recreational sites can pose a health hazard. The presence of fecal material and urine from overuse, or insufficient number or inadequate maintenance of facilities can be dangerous to public and wildlife health in riparian areas. Suspended solids and additional nutrients in the stream also can be detrimental.

Increase in nutrients can cause algae blooms and depletion of oxygen from the water can degrade aquatic habitat. Degradation of streams and the riparian habitat will directly influence fish habitat and the quality of fishing activities.

Disturbances to the soil can lead to erosion and movement of both organic and inorganic materials into streams. Off-road vehicles disturb soils and vegetation increasing soil erosion in both riparian and upland areas. Trampling of vegetation and compaction of soils along banks of streams and rivers can occur. The reduction in vegetation may eventually reduce the amount of organic material entering the system. If reduced below a threshold level, this loss of organic material may be detrimental to aquatic life dependent upon it as a source of energy. Off-highway or off-road vehicles driven in stream channels may destabilize streambanks changing the channel geometry.

Disruption of wildlife also is an issue. Many people enjoy seeing wildlife as part of an outdoor recreational experience. Sometimes these pursuits are intrusive into protected wildlife areas. Riparian lands set aside for wildlife refuges along the Colorado River provide a level of protection for the site and its habitats as well as allow recreational bird watching. Activities such as camping and boating are currently restricted in certain areas. Indirect effects on wildlife include disruption of normal behavior patterns by physical presence of people or by noise.

In urban areas, golf courses, tennis courts, ball fields, and other recreational facilities can be found in riparian areas. Some recreation areas such as Indian Bend Wash are designed to be inundated during heavy runoff events. Water removal for irrigating golf courses and ball fields may directly affect riparian areas.

Management

Recent surveys by the Morrison Institute (1992) and by Arizona State Parks (1992) have made it clear that many Arizonans value water-based recreational opportunities. Education of recreation users and well located and designed facilities may reduce the overall impact. Multiple use management on federal lands recognizes that conflict will occur between recreation and other public land uses. One method of protecting riparian areas may ultimately require limiting public access to some parts of the these dynamic but fragile ecosystems. Federal land management planners often employ a separation of activities to avoid conflicts. **Table 7** is a list of protective measures that could be used for recreation activities.

In Arizona, spatial separation is employed to limit or minimize the conflicts. For example, the restriction on camping by hunters within 0.25 miles of a spring or water source promotes use by wildlife (A.R.S. §17-308). This reduces the direct effect on the wildlife component of riparian areas.

Siting of facilities such as restricting new facility construction within a buffer zone along riparian zones or other sensitive areas also provides protection . Relocating existing facilities away from riparian areas, the closure of areas and the restriction of activities in certain areas are other practices.

Adequate staff presence and enforcement of regulations helps to eliminate potential problems but by itself is not the answer. The size of many of the areas, as well as the distance necessary to travel often limits oversite by land management personnel. Resources and personnel to oversee the areas are often limited.

Educating people on the value of riparian areas may change peoples attitudes and ultimately change behavior. Development and implementation of an educationally based, ecologically oriented management program will possibly provide a method by which land managers can ensure a healthy environment for future generations to enjoy high quality outdoor recreational experiences.

Table 7. Protective management practices for recreational use and development activities.

RIPARIAN AREAS PROTECTIVE MANAGEMENT PRACTICES for RECREATIONAL USE AND DEVELOPMENT
• Designate some riparian areas as restricted or off-limit
• "Unique Waters" designation
• Facilities set back from riparian areas
• Provide buffers for riparian areas
• Educate public on importance of riparian areas
• Limit use of areas for particular times of the year
• Limit number of users or type of use
Sources: ADEQ, 1992; ASP, 1989; Field et al., 1985.

Commercial, Industrial and Residential Development

Description

The historical development of cities and towns in Arizona has almost exclusively been dependent upon the **availability of water** (either surface or groundwater). In the early years of European settlement, the pattern of development followed a sequence initiated by the presence of a mission, hacienda, ranch or farm, or a hastily constructed boom town to serve a new mining discovery (Haskett, 1935). The lack of bridges over the major waterways meant that established fords or ferry crossings became logical locations for development. Later in the European settlement era, especially with the arrival of the railroads and the automobile, major crossroads or railroad water stations became sites for development.

The State's relatively mild climate has attracted people from many regions. Early Spanish and Mexican settlers built towns in southern Arizona including Tubac and Tucson. The construction of the railroads tied with the discovery of rich mineral deposits led to boom towns across the territory. After statehood, the economy eventually became largely dominated by agriculture (cotton), mining (copper) and cattle. The second World War introduced aeronautical technology and military training to the State. An improved road network opened the State to a wide array of visitors, some of whom eventually returned and established residency.

Introduction of large scale air travel also allowed for a greater influx of visitors. The advent of air conditioners also made life much more comfortable for people living in the Sonoran Desert. Tourism and the convention industry are now an important part of the State's economy that supports many food service, lodging and meeting facilities. Electronics and high-tech industrial growth has also supported an expanding economy and influx of highly skilled workers.

Commercial, industrial and residential development has occurred in riparian areas. Increased population has created a demand for the use of riparian areas for construction of houses and businesses. The unpredictable and often long interval between large flood events, as well as a sense of security created by upstream dams, has often drawn development onto the floodplain. These land uses in riparian areas are not limited to the major metropolitan areas of Phoenix and Tucson. They can be found in Cottonwood, Duncan, Camp Verde, Tempe, Bullhead City, Yuma, Sedona and other cities. Urban development has occurred in lowland areas along transportation routes where water is available and land is relatively flat for ease of construction. Land prices have often been lower along rivers and streams, especially in the low, floodplain lands.

In other areas such as along Oak Creek, Tonto Creek and the Verde River, high values have been placed on streamside properties. If the riparian area has an outstanding natural quality, residential occupants find it a desirable place for an exceptional quality of life. Construction of vacation or retirement homes, road and utility networks and the septic systems to service them have affected riparian areas.

Effects

A summary of the effects commercial, industrial and residential development have in riparian areas is presented in **Table 8**. The primary effects are dependent upon whether or not the activity occurs directly in the floodplain. Where development has occurred in riparian areas, the effects have been direct and have contributed to the loss of riparian areas.

The establishment of residential, commercial, and industrial development in or adjacent to riparian areas has caused subsequent effects to occur in riparian areas as a result of this activity. Flooding in some established developments in Arizona is due to their location on the floodplain; Hound Dog Acres residential development in the vicinity of the Salt, Gila, and Agua Fria rivers; Punkin Center on Tonto Creek; Winkleman Flats along the Gila River; Sedona on Oak Creek; Cottonwood on the Verde River; and Clifton on the San Francisco River.

Flood control dams, channelization and bank stabilization projects have been designed to protect the inhabitants at the expense of the riparian ecosystem. As an example, much of west-central Phoenix falls in the floodplain of Cave Creek Wash, once a free flowing intermittent stream. The construction of the Cave Creek Dam and the Arizona Canal Diversion Channel (AC-DC) has encouraged urbanization into this area. The presence of upstream dams often provides a sense of security for developments to encroach further into the floodplain. This security however, as subsequent flooding has illustrated, is sometimes false.

The expansion of cities and towns has increased the need to provide waste, wastewater and sewage facilities. Illegal dumping has occurred in riparian areas by individuals unwilling to dispose of waste materials properly. Abandoned sand and gravel pits located in river channels have been used in the past as landfills.

The need for raw materials, such as sand and gravel used in construction, has put pressure on sand and gravel operators to obtain materials from easily accessible deposits at sites which are frequently located in riparian areas. The increased need for electric power in urban areas has influenced dam construction and reservoir operations. Utility lines both follow and cross riparian areas. Roads and bridges connect parts of cities divided by rivers and their riparian areas.

Parking lots and roads are impervious surfaces causing an increase in runoff. The introduction of chemicals such as industrial solvents, heavy metals, paint thinners, oil, grease, antifreeze, pesticides, fertilizers and detergents into waterways or ground water either directly or from stormwater runoff, is an on-going problem. These chemicals and other urban pollutants vary in their toxicity. They can affect riparian area vegetation or wildlife. In instances where accidental spillage of hazardous materials occurs and the materials are carried into riparian areas the effects are immediate and severe. In other cases, the discharge of seemingly low levels of contaminants to riparian areas can occur over many years or decades.

Table 8. Effects of commercial, industrial and residential development activity.

EFFECTS ASSOCIATED WITH COMMERCIAL, INDUSTRIAL AND RESIDENTIAL DEVELOPMENT	
DIRECT	**INDIRECT**
Discharges from industrial or commercial facilities	Potential human health problems Degrades aquatic habitat
Remove riparian vegetation	Habitat alteration Increase in water temperature Decrease in oxygen content in water Increase pH of water (more acid) Increase sediments Increases runoff
Grading, surface disturbance	Alter channel material Alter channel geometry Downstream channel changes Increase sediments Change in stream hydrology/hydrography
Paving / surface compaction	Increase in pollutants Increased runoff / peak flows Increase flood damage Downstream channel changes
Reduced infiltration in watershed	Increased streamflow
Use of pesticides and fertilizers	Potential human health problems Degrades aquatic habitat
Subsequent effects	
Removal of water surface water diversions groundwater pumping	Decline/death of riparian vegetation
Construction of sanitary facilities	Potential human health problems Increase in aquatic plants in treated discharges

Sources: USEPA, 1993; ADEQ, 1992; Leopold, 1968; Schueler, 1987; Schueler et al., 1992; Odemerho, 1992; Gregory, 1992; Newberry, 1992

These low levels of pollutants can be accumulated in tissues of both plants and animals found in riparian areas and eventually reach levels that may be toxic. Tracking the movement and identifying the source of lower levels of contaminants can be difficult. Low level nonpoint source discharges of pollution are often concentrated in and around cities and towns.

Management

Settlement and development often followed on previously cleared agricultural lands that were cleared long before there was a concern for floodplain management. Much of this development took place before any effort to limit such activities in areas susceptible to flooding. Today, zoning or other mechanisms such as the costs and availability of insurance, can limit locating homes and businesses in the floodplain.

Except for ease of access to water and the economics involved with private ownership and private property, it is not essential that commercial, residential or industrial development activities be located in riparian areas. The possibility of flooding is always present. Economic considerations such as insurance cost, personal safety, and property protection directly influence the development in flood hazard areas.

Floodplain use permits and the Federal Emergency Management Agency (FEMA) regulations now attempt to govern and limit the extent of future development in areas susceptible to flooding. However, the availability of desirable land and real estate values still result in development in some riparian areas.

The occurrence of current and future development of commercial, residential or residential sites in riparian areas is more highly scrutinized. The regulations of FEMA and the flood control districts are for protecting the property and personal safety of the floodplain's potential users. Protection of riparian area habitat is secondary and seldom considered.

Local zoning or planning commissions can help guide construction, sometimes taking environmental factors into consideration. The location of residential,industrial and commercial facilities may be found on public and private lands, however, the majority of these activities occur on private lands. Military bases and facilities are examples of public sector concentration of similar land uses near riparian areas.

The majority of development of commercial, residential, and industrial land has occurred outside of riparian areas. The presence of development in the uplands does have several effects on riparian areas. Increased human population places a higher demand on limited water resources, both surface and groundwater. Management of these important secondary effects of these development activities is important in any consideration of riparian area protection measures (**Table 9**).

Table 9. Protective management practices for commercial, industrial and residential development activities

RIPARIAN AREAS PROTECTIVE MANAGEMENT PRACTICES
for COMMERCIAL, INDUSTRIAL AND RESIDENTIAL DEVELOPMENT ACTIVITIES

- Zoning ordinance to limit development
- Flood plain use permits
- Insurance rates (expense deterrent)
- Limit vegetation clearing
- Use of vegetation as filter strips
- Filtration basins for runoff
- Education of public and developers on riparian values

Sources: USEPA, 1993; von Oppenfeld and Hiser, 1992; Newberry, 1992.

Road and Bridge Construction

Description

The historical development of the existing network of roads and bridges in the state of Arizona has followed the usual logic of people needing to move themselves and their goods or services in the most direct route available. At times, this has resulted in construction in less than suitable terrain. Historically, the path of least resistance was frequently along game trails and alongside streams and rivers. Construction of bridges over the major waterways came later in the European settlement era for railroads and later for automobile routes.

The varied climatic regions, terrain and geological obstacles present in Arizona have dictated a wide range of road and bridge designs. Over the last four decades, increased populations and demand for greater mobility has required improvements and upgrades for these structures.

The alignment of roads can cross many land ownership categories. Private land owners construct access roads on their property. Municipalities, counties, federal agencies and the State Department of Transportation all construct and manage roads within their jurisdictions.

Effects

The direct effects of road and bridge construction activities will occur if they are located within riparian areas. The effects of road and bridge construction activities relative to riparian areas are presented in **Table 10.**

The design of roads and bridges considers the erosive forces detrimental to the stream's hydrologic and geomorphologic regimes (ADOT, 1990). Downcutting, deposition of material, widening of stream channels, and flood flows can occur which can eventually compromise the stability of the bridge. Road and bridge construction may change the terrain within the roadway right-of-way. This includes the removal of vegetation, loss of wildlife habitat, disruption of wildlife movements, soil compaction or disturbance, and water pollution. Disturbances to the soil during construction result in easier erosion and movement of both organic and inorganic materials into streams.

Design, planning and construction of roads and bridges can influence the safety of the road or bridge. Streamflow, both upstream and downstream, may degrade water quality due to an increase in sediments. Upstream head-cutting and bank erosion may occur from road crossings. Bridges may constrict the channel increasing flooding on the upstream floodplain, increasing the velocity and erosion capability of the water directly downstream, and cause a cutting off of floodplains directly downstream.

Construction materials such as sand and gravel are typically used in road and bridge construction. These sources are usually located in floodplains. Vegetation removal, soil disturbances, and increased runoff and sediments into the channel can result.

Table 10. Effects of road and bridge construction activities.

EFFECTS ASSOCIATED WITH ROAD AND BRIDGE CONSTRUCTION	
DIRECT	**INDIRECT**
Remove riparian vegetation	Habitat alteration Increase in water temperature Decrease in oxygen content in water Increase pH of water (more acid)
Alter water drainage	Increase streamflow velocities Increase channel degradation Increase channel headcutting
Alter channel geometry	Decline/Death of riparian vegetation Channel instability Increase channel slope Increase channel degradation Aggradation of channel materials downstream Decrease aquatic habitat Loss of pools & riffles
Soil disturbance, construction	Alter channel geometry Degrade aquatic habitat Sediments increased
Barrier to wildlife and fish	Degrade aquatic habitat
Increase human access	Possible degradation in entire habitat
Increase pollutants (oil spills, de-icing, etc.)	Degrade aquatic habitat Increase sediment
Obstruct streamflow	Increase flow velocity Alter channel geometry
Alter channel materials	Increase bed armoring
Sources: USEPA, 1993; Zeedyk, 1990; Levinski, 1982.	

In the arid regions of the State, the construction of small culverts in ephemeral streams allows water to flow under the roadways after heavy rains. In some instances, intermittent streams have been cut off or diverted.

Roads constructed in higher elevations of the State must be maintained for safety reasons. The procedure when there is snow on roadways and bridges may be the addition of salt, cinders, or other materials to melt ice and snow. There is a potential source of contamination in riparian areas receiving runoff from the roads in the winter or spring.

Management

Evaluating current road and bridge construction activities in riparian areas reveals there is a greater awareness of the fragility and importance of those areas in all project phases. Management practices to reduce effects are listed in **Table 11.**

The implementation of effective design engineering and construction techniques are recognized as the way to reduce the effects that are anticipated to occur. Construction activities that involve federally delineated areas such as ordinary high water or wetlands will be required to follow the permit procedures of the Section 404 Clean Water Act. Some bridges do not directly affect the riparian area because they are suspended above the channel.

The planning and design phases are the ideal times to incorporate protective measures (USEPA, 1993). Effects of road and bridge construction may diminish over time as the environmental system adjusts. This natural healing of riparian areas can occur when the road or bridge is properly designed and careful attention is given to best management practices during the construction phase. Subsection 107.15 of the 1990 Arizona Department of Transportation Standard Specification for Road and Bridge Construction, "Prevention of Landscape Defacement; Protection of Streams, Lakes and Reservoirs:" delineates the practices a contractor must follow to minimize the effects of their activities on streams and lakes.

As Arizona's population grows, the demand for accessibility will increase. The tradeoffs of providing safe transportation routes and the desire to protect riparian areas must be carefully considered.

Table 11. Protective management practices for road and bridge construction activities.

RIPARIAN AREAS PROTECTIVE MANAGEMENT PRACTICES for ROAD AND BRIDGE CONSTRUCTION
• Establish setback distances or buffers
• Site, design and maintain bridge structures to protect aquatic ecosystems and water quality
• Limit land disturbance and vegetation removal
• Avoid locations requiring excessive cut and fill
• Avoid the use of oil or deicing salts for seasonal maintenance near areas of concern
• Evaluate present hydraulic conditions to prevent channel constriction and degradation
• Mitigate effects of construction by restoring riparian vegetation and channel geometry
• Use nonstructural bank stabilization methods to protect road and bridge structures
• Protect existing streamside vegetation whenever possible during construction
• Place culverts to prevent headcutting and dewatering
Sources: USEPA, 1993; AASHTO, 1991; Levinski, 1982; Zeedyk, 1990.

Dam and Reservoir Construction

Description

Although the definition of riparian area in A.R.S §45-101 excludes "man-made storage reservoirs constructed primarily for conservation or regulatory storage", the statute mandates that ADEQ "shall evaluate ... 6. Dam and reservoir construction and operation" (A.R.S. §45-101.6.A.). For the purpose of this report the effects of dam and reservoir construction on downstream and upstream riparian areas were evaluated.

The waters flowing through riparian areas follow seasonal patterns. There are many purposes for constructing a dam, including municipal water supply, flood control, power generation, irrigation, and livestock watering. Dams are divided into four classes, 1) run-of-the-river, 2) mainstem, 3) transitional, and 4) storage (USEPA, 1993). These classes vary in storage area, height of dam, detention time, and reservoir depth.

The steps involved in dam construction start with an identification of a need for flood control, water storage, or electricity production. Potential sites are selected and evaluated in the planning phase. An environmental analysis must be conducted before there is approval and funding provided for the project. Site selection, construction, and operation cause a variety of effects. The release of water is regulated according to the primary purpose of the dam.

Effects

The construction of dams has had the most far-reaching effect on riparian areas. There is a strong cause and effect relationship. **Table 12** gives an overview of dam and reservoir construction in relation to riparian areas.

Reservoirs initially inundate existing riparian areas. These areas do provide recreational opportunities. The operation and control of releases have altered or removed streamflows, reduced seasonal flow patterns (hydrograph), and altered water quantity. Ground water recharge is reduced downstream. Recruitment of vegetation is inhibited due to the lack of high flows, leaving only old-age forests of riparian vegetation such as cottonwoods and willows. Some areas have stands of salt cedar, an exotic plant species, that can tolerate drier conditions. Populations of native fishes have also been affected by the series of upstream dams and water diversion projects.

The downstream effects dams have on channel geometry are degradation of the channel bed and channel armoring (Graf, 1988). These effects are caused by sediments being trapped behind the dam. Water released is relatively free of sediment. These releases are capable of picking up or transporting sediments from the channel bed. The elevation of the channel bed is lowered (degradation) and only large boulders and cobbles remain on the channel bed (armored).

Table 12. Effects of dams and reservoir construction and operation activities.

EFFECTS ASSOCIATED WITH DAM AND RESERVOIR CONSTRUCTION AND OPERATION	
DIRECT	**INDIRECT**
Obstruct streamflow	Eliminate lateral movement of sediments Decline/death riparian vegetation Decrease aquatic habitat
Increase stability of floodplain	Increase urban encroachment Reduce flooding
Alter channel material	Increase sediments Decrease aquatic habitat
Remove/divert streamflow	Decline/death of riparian vegetation Decline/death of aquatic habitat Decline/death of wildlife Reduce flood flows Lack of recruitment of riparian vegetation
Remove riparian vegetation	Habitat alteration Increase in water temperature Decrease in oxygen content in water Increase pH of water (more acid) Decrease in age classes of vegetation Habitat alteration Decrease in biodiversity
Alter channel geometry	Decline/death of riparian vegetation Increase channel degradation Increase channel armoring Decrease aquatic habitat
Management of releases	Lack of sediment deposition for seedbeds Downstream scouring/erosion Increase urban encroachment Alter channel geometry Decrease water temperature Decrease aquatic habitat Eliminate lateral movement of water surface water groundwater
Reduced effects of cattle - stocktanks located in upland areas	Limit bank instability in riparian area Limit fecal material in stream Increase water availability for wildlife

Sources: USEPA, 1993; Graf, 1988; Brinson et al., 1981; Simons, Li and Associates, 1982; Williams and Wolman, 1984; Petts, 1984; Lillehammer and Saltveit, 1984; Reily and Johnson, 1982; Baxter, 1977; Harris et al., 1987; Nilsson, 1982; Teskey and Hinckley, 1977; Ward and Stanford, 1979.

Dam construction has had a direct effect on human population patterns. People have settled in those parts of the State that have reliable supplies of water such as in the Salt River Valley. The reduction in flooding has caused urban areas to encroach further onto the floodplain.

With the increased population, there has been a corresponding increase in other activities, including agricultural land clearing, urban development, development of water supplies (surface and groundwater), wastewater treatment facilities, and landfills.

Dams can have a positive influence on riparian areas. The regulation of flow patterns eliminates high flood flows and scouring of vegetation. Vegetation can expand into the channel downstream of the dam. Ponding of water in reservoirs allow establishment of riparian vegetation. Whitlow Ranch Dam, a flood control dam on Queen Creek, has had extensive riparian vegetation growth behind the dam (Szaro, 1989). Cattle utilizing stocktanks and small dams constructed on upland areas can reduce the use of riparian areas by these animals.

Beavers also construct dams. The U.S. Fish and Wildlife Service and the Arizona Game and Fish Department have reintroduced beavers along sections of streams in Arizona. The effect of a beaver dam is local. Areas that are inundated are often increased creating wetlands (Naiman et al., 1988). Water quality (decrease water pH and increase nutrients) and flow regime are locally affected.

Management

Activities that remove water from the stream, such as dams and diversions, significantly effect riparian areas by limiting water availability. Dams that are constructed either using federal dollars or occurring on federal lands require the preparation of Environmental Assessments (EA) and Environmental Impact Statements (EIS). In these reports, alternatives are proposed; avoidance or no action, minimization of impacts, or compensation for the impacts (National Environmental Policy Act, 1969). Some of these practices are presented in **Table 13.**

Table 13. Protective management practices for dam and reservoir construction and operation.

RIPARIAN AREAS PROTECTIVE MANAGEMENT PRACTICES
for DAM AND RESERVOIR CONSTRUCTION AND OPERATION

New dams (proposed)

- Avoidance of critical sites
- Minimization of effects to critical sites
- Construction procedures designed to limit sediment discharges
- Preserve riparian vegetation that already exist near the dam construction site
- Operation of dam to protect riparian vegetation downstream

Dams currently operating

- Releases which support riparian vegetation and wildlife (instream flow)
- Releases of yield from sediment reserve storage for augmenting instream flows
- Release patterns to enhance downstream riparian vegetation recruitment

Sources: USEPA, 1993; Brookes and Gregory, 1988; Brinson et al., 1981; Nelson, Horak and Solomon, 1978.

Channelization and Bank Stabilization

Description

Channelization and bank stabilization occur exclusively in waterways. They occur in or along intermittent and perennial streams of many sizes throughout the State. These projects are implemented to improve the conveyance of water while protecting human life and property. They also are used to protect highways, roads and bridges.

Channelization and bank stabilization activities occur in waterways and therefore require issuance of a Clean Water Act Section 404 permit before a project can proceed.

Channelization often requires reworking the channel bed, disturbing or destroying the natural amour layer (Simons, Li and Associates, 1982). Irregularities such as meanders or large boulders are straightened or removed and the channel itself is narrowed. The purpose is to alleviate overbank flooding on adjacent lands. Design, engineering and construction are intended to facilitate nondestructive flows near the project.

Bank stabilization is conducted to prevent the erosion of bank material into the channel. The size and scale of bank stabilization projects range from local plantings of riparian trees to intensive engineered methods such as soil cement, riprap, and concrete structures. Bank stabilization using riparian vegetation to stabilize bank materials can enhance riparian habitat.

Effects

Channelization and bank stabilization activities affect channel geometry and hydrology which consequently affects the riparian area. These activities straighten, enlarge, harden, and/or relocate the natural channel. Large scale, extensive disturbances and changes will eliminate riparian ecosystems. Modifications are made to the channel that changes the gradient, the form and surface composition (i.e. armored, unarmored). An overview of these activities is shown in **Table 14.**

Dredging and filling of lands in riparian areas are part of the process. These involve changes to the channel structure that change the amount and the location of sediment deposits. Materials are removed and deposited to reduce the grade, widen or deepen the channel and to allow for faster flow through the system. This rapid flow may reduce the time that the water is present in the channel or on the floodplain which reduces aquifer recharge.

Downstream effects are also evident in that increased, rapid flows through channelized sections can be the catalyst for changes downstream. Impacts of increased water velocity on downstream riparian areas may prevent damage in one area, however, the problems are just moved. Critical flows moving down stream can consequently overwhelm other flood structures. An example is the breach of Gillespie Dam during flooding on the Gila River after extensive clearing of vegetation upstream.

Table 14. Effects of channelization and bank stabilization activities.

EFFECTS ASSOCIATED WITH CHANNELIZATION AND BANK STABILIZATION ACTIVITIES	
DIRECT	**INDIRECT**
Impervious surface/soil compaction	Increase runoff / peak flows Increase contaminants into water
Increase stability of floodplain	Increase urban encroachment
Alter channel materials	Increase sediments Increase bed armoring Decrease aquatic habitat
Removal of riparian vegetation	Habitat alteration Increase in water temperature Decrease in oxygen content in water Increase pH of water (more acid)
Straighten channel - alters channel geometry	Decline/death of riparian vegetation Decrease channel sinuosity Channel instability Increase channel slope Increase channel degradation Aggradation of channel materials downstream Decrease aquatic habitat
Line channel	Increase stability of floodplain Increase channel slope Restrict lateral movement of water surface water groundwater Restrict lateral movement of sediments Decline/death of riparian vegetation Lack of sediment deposition for seedbeds
Increase pollutants downstream	Low flow channel abandoned Increase urban encroachment Decline/death of riparian vegetation Reduce filtering of pollutants Increase sediment Increase nutrients

Sources: USEPA, 1993; Brinson et al., 1981; Brookes and Gregory, 1988; Rhoads, 1989; Heede, 1986; Simons, Li and Associates, 1982. Hupp, 1992.

These activities also often involve vegetation removal. Streamside vegetation is removed during channelization or shortly afterward through channel responses to channelization (Hupp, 1992). The result is that the natural biological system is eliminated in that area.

For downstream areas, seed sources are removed. There is an overall break in the river continuum.

Management

Of concern to decision makers and design engineers is the lack of predictability of when maximum water flows will occur and how large they will be. Statistical rainfall and runoff projections can be fairly accurate. Designing channelization and bank stabilization projects to withstand the projected extremes can be done. However, the realities of project costs and undesirable direct effects of implementation (in some cases, loss of riparian habitat) can restrict their construction. More cost effective and environmentally sensitive alternatives may be necessary. Of course, it also is possible to enhance riparian areas through these activities (DeBano and Heede, 1987).

Management of water quality in riparian areas in relation to these activities is regulated by law. Under ordinary conditions, dredging and filling activities that discharge into waters of the United States must be permitted through the Clean Water Act (CWA), section 404 and State Certification of those permits, section 401. Attainment of Clean Water Act goals and maintaining water quality standards to support the designated uses are the primary objectives. In the permitting process the existing physical, biological, and chemical conditions at the site are considered, as well as the projected impact of the proposed activity. The process reduces the likelihood that any activity will introduce contaminants into the waters that would degrade water quality. These activities can be done in an ecologically sound manner **(Table 15)**.

Table 15. Protective management practices for channelization and bank stabilization activities.

RIPARIAN AREAS PROTECTIVE MANAGEMENT PRACTICES for CHANNELIZATION AND BANK STABILIZATION

- Avoid disturbance to riparian areas
- Evaluate channelization design to minimize disturbance to riparian areas
- Integrate channelization design to maintain floodplain vegetation
- Use of nonstructural bank stabilization methods to reduce barriers to subsurface water flow
- Maintain vegetation in channel when possible

Sources: USEPA, 1993; Brookes and Gregory, 1988; Brinson et al., 1981; Henszey et al. 1989; DeBano and Heede, 1987.

Sand and Gravel Extraction

Description

The location of sand and gravel extraction activities often occur in stream channels and on the adjacent floodplain. These activities depend upon the deposition of alluvial materials. Natural movement of eroded rock of all sizes, subsequent tumbling, and deposition of those sediments in graded or sorted deposits is a fundamental geomorphological process found in riparian areas. Sand and gravel deposits of various sizes can be found in stream channels and on adjacent flood plains. Past water actions have often sorted and graded these materials making them economical to extract. Deposits can be found away from current waterways as a testament to the constantly changing erosional landscape.

As the most basic components of concrete and asphalt, these materials have been crucial for economic development. Rock products have been used in all phases of construction and development in the State. Utilization of rock products in Arizona has been influenced by transportation costs. The materials are heavy and expensive to move great distances. This has often meant that developers have sought to purchase materials from the nearest sand and gravel operation. Also, there have been specially constructed sites for extraction of materials as close as possible to the site where the materials are needed (i.e. along highways or near construction sites).

Exact numbers of sand and gravel sites were unavailable for this evaluation. Sites range from borrow pits alongside highways and roads to large commercial extraction sites. Borrow pits often occur where a stream intercepts transportation routes. It has been estimated there may be many as 6,000 site in the State. The number of large commercial sites may be more than 200 across the State.

The construction of upstream dams allowed for greater accessibility to deposits along once perennial rivers such as the Salt River and Gila River. In the arid regions of the State, the intermittent and ephemeral character of the streams has allowed for extraction to progress without fear of constant flooding. Water is often utilized in the processing of the materials such as for washing.

Effects

The effects on riparian areas are often fairly local in extent. However, depending on the size of the operation, they can alter stream hydrology upstream and downstream. Sand and gravel materials will continue to be in demand as urban areas expand and develop. A general overview of the effects sand and gravel operations have in the riparian areas of the State is presented in **Table 16**.

This activity directly affects the structure of the channel and the floodplain. The activity changes the biotic communities present at the extraction site by removing vegetation. Channel structure is affected through the construction of temporary and permanent levees to protect these operations which alter streamflows. This can affect nearby lands and man-made structures such as bridges, power poles, and underground pipelines.

Table 16. Effects of sand and gravel extraction on riparian areas.

EFFECTS ASSOCIATED WITH SAND AND GRAVEL EXTRACTION	
DIRECT	**INDIRECT**
Obstruct streamflow	Decrease aquatic habitat Decline/death of riparian vegetation Change of age class of riparian vegetation
Remove riparian vegetation	Habitat alteration Increase in water temperature Decrease in oxygen content in water Change in pH of water Increase sediments
Increase contaminants into water	Decreases water quality Degrades aquatic habitat
Alter channel geometry Lower channel bed Alter channel banks Increased channel bank instability	Increase upstream headcutting of channel Decline/death of riparian vegetation Channel bed lowered upstream & downstream Decrease of aquatic habitat Undermines bridge supports, pipelines and other structures Lowers groundwater table Decreases flooding Channel widening Decrease bank stability Increase erosion / sediments
Lowers groundwater table	Death/decline of riparian vegetation
Abandoned pits - used by wildlife	Increase wildlife habitat / bird-watching sites
Abandoned pits - used as landfills	Increase pollutants
Remove / divert water	Death/decline of riparian vegetation Alter channel geometry
Increase runoff, erosion, water yield	Increase sediments into channel Decrease aquatic habitat
Soil disturbance	Increase sediments into channel
Alter channel materials	Increase sediments into channel

USEPA, No date; UD & FCE, 1987; Collins and Dunne, 1990; Simons, Li, Assoc., 1982.

The large scale removal and excavation of material also can intercept the watertable and thus affect the availability of subsurface water for downstream riparian areas. As with all the other activities involving heavy equipment, the presence of vehicles and heavy machinery are also a potential source of water contamination.

According to Roberts (1991), there are five types of impacts of gravel mining operations on river hydraulics and sedimentation processes in relation to bridges. These effects are, upstream headcutting of gravel pits, lateral migration of pits, local scour effects near levees, bridge piers and other structures; and obstruction of flow by tailings piles, equipment and roadways. The extent of these effects depends upon local characteristics such as the hydraulics, location and size of pits or obstructions, the shape and duration of the hydrograph, and sediment transport. The severity of the effects is dictated by the pit volume and depth. Animals, trees, shrubs, and other vegetation are affected within riparian areas.

Management

Sand and gravel extraction occurs where the raw materials are present. Protective measures that could be used for sand and gravel extraction activities that would minimize the effects to riparian areas are listed in **Table 17**.

Activities that occur within Ordinary High Water or in delineated wetlands (both areas determined by the U.S. Army Corps of Engineers) are required to have a Section 404 permit and a Section 401 State Water Quality Certification and a Floodplain Use permit. Protective measures for those activities that require a 404 permit are handled as part of the permit conditions.

Those operations located within the floodplain but outside the Ordinary High Water line or within delineated wetlands are required to have a Floodplain Use permit issued by the county flood control districts. The Floodplain Use permit is concerned primarily with an operation obstructing the conveyance capacity of the channel during a high flow event.

Goal oriented Best Management Practices (BMPs) and Guidance Practices (GPs) for sand and gravel activities are being developed by a technical advisory committee (coordinated by the Nonpoint Source Unit of ADEQ) of which the Arizona Rock Product Association is a member. The BMPs are broad statements that apply statewide. The principal goal of the BMPs is to minimize the effect sand and gravel activities have on water quality. A guidance document is anticipated in early 1994, with rule-making beginning in late 1994 with the intent of incorporating goal oriented BMPs into rule.

Table 17. Protective management practices for sand and gravel extraction activities.

RIPARIAN AREAS PROTECTIVE MANAGEMENT PRACTICES
for SAND AND GRAVEL EXTRACTION ACTIVITIES

- Avoid areas with high quality riparian habitat

- Avoid removing material below the water table

- Selective or minimum clearing of riparian vegetation from site

- Maintain channel integrity
  - Avoid placement of structures in channel
  - Stabilize channel banks
  - Grade control structures utilized to protect headcutting
  - Runoff and sediment retention structures

- Reclaim abandoned pits
  - Utilization by wildlife

- Recontour and revegetate pit banks to stabilize soil and enhance habitat

- Revegetate material processing and storage sites after completion of operation

- Limit total volume of gravel extraction in the stream reach to the effective rate of supply received from upstream

- Control pollution

Sources: USEPA, No date; UD & FCD, 1987; Matter and Mannan, 1988; Collins and Dunne, 1990; Roberts, Horn and Chen, 1981; Hart and Assoc, 1992.

Wetland Drainage

Description

In Arizona, the arid to semi-arid climate is not conducive to extensive wetlands such as those found in the Eastern part of the United States. However, where local geologic and hydrologic conditions are favorable, wetlands have developed. The most important component, **water**, must be present in sufficient quantity and for a sufficient period, to support a community of plants typical of wetlands. Wetlands do not always occur next to a stream or a river. They also can occur on upland areas that are poorly drained. Wetland plants differ from plants in the uplands due to saturated soil conditions.

Wetlands are defined as "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands include swamps, marshes, bogs, cienegas, tinajas and similar areas" (Arizona Administrative Code R18-11-101).

All riparian areas may be considered wetlands (from a western, arid region perspective). Riparian areas and wetlands perform similar functions. In the 1988 Arizona Wetlands Priority Plan, the Arizona State Parks discuss the wetlands resources in Arizona. The discussion reviews several definitions of wetlands and riparian areas. Their comparison of definitions indicated there is "a consistent trend in scientific thought that riparian communities in this arid region are indeed wetlands."

The evaluation of wetland drainage activities includes any activity that removes or diverts water from a natural system by any means, such as by dams, diversions and groundwater pumping. Of all the activities evaluated, this activity possibly places riparian areas and other wetlands in the most precarious position, for without water present in the system, the plants, insects and animals cannot exist.

Historically, wetlands were more extensive along perennial streams in the past(SCORP, 1989; Hendrickson and Minckley, 1985). Some wetlands, including those associated with local springs and seeps, provided refuges for species needing a reliable source of water. Species composition of wetlands varies according to elevation, latitude and local biotic community factors. Many rare plant and animal species are found in wetlands.

Wetland drainage occurred to open new areas for land development or agriculture or to allow easier construction of roads, railroads or towns. These areas were often seen as useless lands, sources of insects, pests and disease. Water intentionally pumped from these areas was used for many other activities, especially irrigation of surrounding lands. The drainage may have occurred indirectly by this same process as water was pumped from aquifers, lowering the water table below the root zones of wetland vegetation.

Effects

Removal of water has a direct impact on wetland ecosystems. Saturated soil produces anaerobic (no oxygen) conditions to which wetland plants are adapted to survive. Permanent removal of water from these areas causes complete collapse of the ecosystem; de-watering of wetlands eliminates all ecosystems components totally dependent upon the high water levels. The effects of wetland drainage are shown in **Table 18.**

Some riparian wetlands are supported by groundwater discharging at the surface. These areas may be drained by groundwater pumping. Water removed from in this way can result in lowering of the groundwater table affecting streams and rivers.

Some areas are capable of actively recharging groundwater. Recharging capability is diminished with soil compaction. This may be a factor if overused by animals or vehicles. Restoration of these areas would be difficult due to the disturbance of the soil structure.

Table 18. Effects of wetland drainage activities.

EFFECTS ASSOCIATED WITH WETLAND DRAINAGE	
DIRECT	**INDIRECT**
Remove/divert water surface water groundwater	Habitat alteration Reduce wetland area Decrease filtering of pollutants Decline/Death of wetland vegetation Vegetation replaced by xeric species (adapted to dry conditions) Eliminate lateral movement of water surface water groundwater Eliminate lateral movement of sediments
Remove wetland vegetation	Increase sediments into channel Increase nutrients into channel Increase pollutants into channel Increase water temperature
Alter channel geometry	Channel instability Aggradation of channel materials downstream Decrease aquatic habitat Increase sediment
Increase stability of floodplain	Increased urban encroachment
Increase pollutants downstream	Threat to human health

Sources: USEPA, 1993; Hammer, 1992; Rodgers and Dunn, 1992.

Management

A list of suggested protective management procedures is presented in Table 19. Wetlands have received a great deal of attention in the last few years. The Clean Water Act, Section 404 permitting program addresses wetland issues when a dredging or filling activity is involved. However, this program does not address diversions and groundwater pumping activities. The Clinton Administration Wetlands Policy (IWGFWP, 1993) "supports the goal of no overall net loss of the Nation's remaining wetlands, and the long-term goal of increasing the quality and quantity of the Nations wetlands resource base."

Avoidance of wetlands and prohibition of draining the remaining wetlands in the State would provide some protection to these areas. If avoidance is not possible, then mitigation should be considered. An activity may be allowed to drain a wetland if there is some replacement or enhancement at another site, preferably within the same watershed. Mitigation may take the form of creating an artificial or human-made wetland. With proper design, management and long-term goals, wetlands can be created which fulfill to some degree, some of the functions of naturally occurring systems.

Table 19. Protective management practices for wetland drainage activities.

RIPARIAN AREAS PROTECTIVE MANAGEMENT PRACTICES FOR WETLAND DRAINAGE

- Avoidance of wetlands and riparian areas
- Minimize withdrawals to allow water for continued support of wetland
- Support the federal policy of no overall net loss of remaining wetlands
- Acquisition of water rights to ensure maintenance of minimum instream flows
- Conduct permitting, certification, and non-regulatory activities in a manner that protects wetland functions
- Require maintenance of wetland vegetation for activities that are known to cause or contribute pollution, including nonpoint source pollution
- Mitigate impacts by restoring or enhancing other wetland areas
- Limit water usage to a level that does not negatively impact wetland area

Sources: USEPA, 1993; IWGFWP, 1993; Kusler, 1983.

Grazing

Description

Except for the harshest terrain such as mountain tops and deep canyons, there are very few sites in the state of Arizona that have not been grazed by cattle or sheep over the last two centuries. If grazing and browsing animals such as deer, elk, and big-horn sheep are included, then it is possible there are few sites in Arizona that have never been grazed.

Early stockmen found that most of the State was suited at some time during the year for grazing. Cattle lived in the open year round on abundant forage.. Shade was abundant and the ranges in the valleys and high mountains were healthy (Haskett, 1935). Pine forests, pinyon-juniper woodlands, grasslands, and desert scrublands offered a variety of areas in which to graze cattle and sheep.

A wide variety of lush grasses and other herbaceous forage could be found on Arizona rangeland. Water was available at springs, and in streams or rivers. Riparian areas provided an attractive source of water and vegetation for grazing animals at all elevations. Native people and European settlers recognized this fact and utilized riparian areas extensively for hunting and for domestic animal herding.

Grazing is the most widespread of all the activities evaluated in this study. It has been present for the greatest period. According to Haskett (1935), the greatest intensity occurred in two distinct periods, with an interim of 50 years between them. The first period was the Spanish-Mexican phase dating from 1700 to 1822. During this period, cattle herds were introduced by missionaries and by Mexican settlers at their many large haciendas. The second phase is the American period that began from about 1872 to the present. With the arrival of the railroads in the late 1800s, new lands were opened for settlement and large numbers of cattle were introduced which could be easily sent back to the markets in the east (Trimble, 1986; Blumm, 1986). The interim years were at the height of Apache activities and ranching operations were not active (Haskett, 1935).

By the middle 1880s, nearly all Arizona rangelands were being used. The flow of cattle from surrounding states and territories was ending. Cattle production exceeded the local military and civilian market demands. As a result, new markets were sought in the East. In the early 1890s, the combination of too many cattle and extensive droughts caused extreme impact to Arizona rangelands and the riparian areas (Haskett, 1935).

The focus and concentration of animals in riparian areas, and the effects of grazing upon watershed conditions makes grazing a significant riparian area activity. The largest expanses of grassland are found primarily on Forest Service lands and State lands at the middle elevations of the State. However, grazing occurs across the landscape at all elevations with concentrated activity within riparian areas. At lower desert elevations the lushest vegetation is found in riparian areas. Cattle are attracted to these riparian areas for shade and water.

Effects

Rangelands that appeared inexhaustible to stockmen in the 1880s began to show signs of decline as ranges were fully utilized. Ranges were overstocked and no areas were left in reserve. Drought conditions that started in the spring of 1891 that lasted through the next two years completely changed the rangelands. By summer of 1892, the grass had practically disappeared from the ranges. Many waterholes had failed and cattle losses were heavy (Haskett, 1935). Rangelands improved after the drought ended in the summer of 1893. However, during the period of drought, pressure by cattle on riparian areas was intense.

Large scale overgrazing in the past has made it difficult to define the original ecological relationships that existed in pre-grazed riparian areas. Climate variability can intensify the effects of grazing as was seen in the 1890s.

Total effects of grazing on riparian areas depends upon 1) the number of animals grazed in an area, 2) proximity to a perennial or intermittent stream, 3) the season of the year, and 4) length of time in the area. **Table 20** presents a summary of identified effects of grazing upon riparian areas in the State.

Grazing effects on water quality and riparian areas are a part of the total agricultural impacts in the State. Agriculture activities are a documented source of contamination to streams. It is the principal land use in terms of area in Arizona. Historic over use of rangeland and irrigated agricultural practices have resulted in the removal or loss of protective vegetation from valley bottoms and desert grasslands. Many agricultural activities contribute to accelerated erosion and high turbidity (ADEQ, 1992, p. 27). Organic and inorganic materials also may be carried into streams.

The affects of overgrazing on riparian areas are: the removal or stunting of young trees, shrubs and grasses; reduction in plant litter; reduced cover for reptiles and amphibians; soil compaction or disturbance; channel and bank disturbance; water pollution; spread of undesirable plant species; reduction in aquatic habitat quality and competition with wildlife for food. If the forage components of the ecosystem are of poor quality, then the grazing value is reduced.

Increased grass cover is desirable for both forage and erosion control. However, if ground cover is overgrazed, resulting increases in runoff and sedimentation can be detrimental to a stream's water flows and channel processes. Detrimental effects include downcutting, deposition of material and widening of the stream channel. Debris flows and flooding resulting from loss of ground cover can affect riparian areas downstream of grazing within the watershed.

Animals whose life cycles are dependent on the riparian habitat are affected downstream. Damaging floods remove streamside plants. Many aquatic species, especially fish, that used the shade and woody material are affected by the removal of plants. Suspended solids and nutrients can enter to a stream from runoff or flooding. Nutrient levels increase because of contamination by animal waste.

Table 20. Effects of grazing activities in riparian areas.

EFFECTS ASSOCIATED WITH GRAZING	
DIRECT	**INDIRECT**
Remove riparian vegetation	Habitat alteration Change in age class and structure of riparian vegetation Increase in water temperature Decrease in oxygen content in water Increase pH of water (more acid) Replacement by less palatable grasses Decrease in aquatic habitat Increase sediments
Remove upland vegetation	Increase runoff Increase sediments
Alter channel geometry - hoof caused bank sloughing	Collapse of bank materials Destabilize bank material Increase sediments in channel Channel widening Decrease in fish habitat
Channel degradation	Water table lowered Entrenchment
Add fecal material to streams	Increase nutrients Increase fecal coliform bacteria
Increase sediments in channel	Degrade aquatic habitat Alter channel materials
Soil disturbance	Trampling Removal of vegetation Increase sediments into channel

Sources: Clary and Webster, 1989; Davis, 1982; Elmore and Beschta, 1987; Chaney, Elmore and Platts, 1990; Meehan and Platts, 1978; Bahre, 1991; Armour, Duff and Elmore, 1991; Cooke and Reeves, 1976.

High nutrient levels and large amounts of suspended solids can be extremely detrimental to fish life cycles (Armour et al., 1991; Meehan and Platts, 1978). On the other hand, plant life cycles may be improved by higher nutrient levels. They may respond by more vigorous growth. This is beneficial only if the vegetation is not immediately removed by the animals.

Changes to plant community structure and the age class structure occur by the direct consumption of the plants and by disturbances to the soil. The most palatable plant species are eaten first. Animals leave the less desirable species. As a result the remaining plants may then have a competitive advantage and become more widespread. Tender, young palatable plants of all species are consumed before they can mature and set seed. This can affect the number of plants if grazing is not managed properly. Only the larger old plants remain in an overgrazed area. Disturbed soils may not allow for the establishment of seedlings of some species and can affect the roots of shallow rooted riparian species.

Riparian plant species can be affected by grazing. Some plant species such as cat-tail, sedges and common spike rush are more sensitive to grazing than others. When these plants are present and accessible, cattle prefer to graze on them. In addition to selective grazing, introduction of exotic species of grasses can alter rangeland ecosystems. The introduced plants are able to establish by out-competing the native grasses.

Management

Evaluation of current grazing practices in riparian areas reveals a greater awareness of the fragility and importance of these areas in overall ecosystem management. The need to balance grazing with the protection of riparian areas is a concern to land managers. This is done using a variety of procedures and practices by grazing managers. Different restrictions are applied by the different land managers on when, how, and where grazing can occur in relation to riparian area. Management committment and follow through also varies considerably.

In light of these variations in management, a recent document entitled Rangeland Reform '94 (USDOI, 1993) has been proposed by the BLM in cooperation with the U.S. Forest Service to "improve management of rangeland ecosystems and the administration of livestock grazing on public lands." The reform acknowledges the need to restore and improve ecological conditions of the rangeland, **including riparian areas.** The BLM and U.S. Forest Service in Arizona have developed management plans to improve the conditions of riparian areas.

The construction of exclosures (e.g., fences) is beneficial to riparian areas. However, water must be available for the cattle and wildlife. Water can be made available by windmill construction for pumping of ground water, stock tank construction upslope, or the diversion of a portion of the surface water to a site outside the riparian area. However, water flow manipulation must not only consider the ecological systems but also the political and legal aspects of western water law and water rights.

In Roché and Baumgartner (1983), forest land grazing is addressed from the standpoint of ecological considerations, plant-animal interactions, uses, and influences. From the BLM perspective, Kinch (1989), discusses the cardinal rules for management of grazing in riparian areas and action planning. The key ecological components include tailoring to site specific conditions, leaving sufficient vegetation stubble, taking advantage of seasonal livestock preference for uplands, resting from grazing whenever possible and appropriate, monitoring the results of designed programs, and adopting management practices which are flexible enough to accommodate changes based on needs.

The significance of effects along perennial streams depends upon the voluntary implementation of best management practices on each ranch or allotment. The Bureau of Land Management (BLM) and the U.S. Forest Service (USFS) have developed guidelines for managing grazing in riparian areas (Clary and Webster, 1989; BLM, 1990). Lands under the jurisdiction of the Arizona State Land Department are not managed specifically for natural resources but are held in public trust for benefit of the educational system of Arizona. In their planning, these agencies also have set objectives for improving riparian area conditions over time.

There are 76.4 million acres in Arizona. Grazing acreage is estimated to more than 41.1 million acres (Burkhart, 1990). This means that more than 53% of the State is currently open to grazing. Of the major non-native American federal lands in Arizona, approximately 14.2 million are under BLM jurisdiction of which 12 million is rangeland; 11.2 million acres are under USFS jurisdiction of which 7.8 million is rangeland and 9.5 million acres are under the State of Arizona of which 8.4 million are grazed. The amount of grazing on private lands is undefined at this time.

An overview of grazing activities was developed by Chaney and Elmore (1991) for the Environmental Protection Agency. Key points are summarized as follows: 1) despite availability of upland forage, cattle tend to concentrate in and overuse riparian areas; and 2), good riparian management is an integral part of increasing a ranch's long-term productivity and profitability. There are several management options to address the first point.

Developing solutions to grazing problems and improving conditions of riparian areas is a priority of many land managers and ranch owners. Goal oriented Best Management Practices (BMPs) and Guidance Practices (GPs) for grazing activities have been developed by a technical advisory group in Arizona. This effort has been coordinated by the Nonpoint Source Unit of ADEQ and has included representatives from the BLM, U.S. Forest Service, Arizona State Land Department, USDA Soil Conservation Service, University of Arizona, Cooperative Extension, Governor's Rangeland Advisory Group, Cattlemen Association and Arizona Wool Growers. A draft BMP guidance document is anticipated from the advisory committee in December, 1993. Rule-making will begin early in 1994 with the intent of incorporating goal oriented best management practices into rule.

Management practices must consider the cyclical nature of extreme conditions and adjust practices to meet the needs of riparian areas during the harshest of times. Proper management by evaluating rangeland conditions and implementing good grazing practices can result in less damaging use. However, these may not be sufficient to offset effects during extreme conditions as occurred in the 1890s. Evaluation and re-evaluation of grazing management practices not only can have a positive influence on the quality of riparian area vegetation, but also on the quality and quantity of water flowing from the watershed into those riparian areas (Ohmart, 1993).

Table 21 presents an overview of some recognized management practices for protection of riparian areas subjected to grazing. Because of the extent of land area encompassed by this activity in the State, positive management can potentially have a significant effect upon the greatest number of riparian areas.

Table 21. Protective management practices for grazing activities.

RIPARIAN AREAS PROTECTIVE MANAGEMENT PRACTICES for GRAZING ACTIVITIES
• Long-term rest to allow recovery; Rest - rotation grazing system (high-intensity, short duration)
• Good range management (Carrying capacity of range balanced with number of animals)
• Improve watershed conditions - reduce overgrazing, improve cover, and control erosion
• Protective fencing
• Timing of grazing - Cool season vs. warm season treatments
• Manage vegetation for minimum herbage stubble height
• Establish special use riparian pastures
• Develop alternative water sources away from riparian areas
• Herding of livestock away from riparian areas
• Salt blocks located out of riparian areas
Sources: GAO, 1992; Clary and Webster, 1989; Davis, 1982; Elmore and Beschta, 1987; Chaney, Elmore and Platts, 1990; Kinch, 1989

Landfills

Description

The Arizona Department of Environmental Quality currently is tracking approximately 211 active landfills of various sizes, types and ownership (ADEQ, 1993).

The quantity of waste material generated varies extensively. Rural, individual or private land holdings produce much less than the cumulative effect of many hundreds of households in towns and cities. Landfill operations range from small, private land dumping grounds and small commercial fill sites, to very large municipal landfills.

Landfills are often located in areas that are lower relative to the surrounding landscape. Often they have used the excavations abandoned by sand and gravel operations. These have a great potential for impacting riparian areas. However, the location and operation of landfills are not dependent on the existence of riparian resources such as water availability or alluvial soils.

Historically, riparian or stream sites have been used as dump sites. Lowlands and floodplains have traditionally been inexpensive lands. Lowlands are convenient places to dump materials. Also, being lower than the surrounding lands, these sites made covering or burying the refuse easier. They were often out of view, and the materials would eventually be washed away and be a problem downstream. Uncontrolled dumping in riparian areas still occurs in rural areas and on the outskirts of large metropolitan areas.

Effects

The direct effect on riparian areas is often only a local and continuous disturbance in the actual vicinity of the facility. Landfills influence riparian areas as presented in **Table 22.**

Landfills can indirectly impact riparian areas by causing materials to seep into groundwater. The earliest landfill methods allowed for possible leakage of contaminants from the landfill into the groundwater which may discharge to streams or surface flows. These landfills potentially contain every contaminant imaginable, which could detrimentally impact the aquatic environment.

Landfills can also directly affect local riparian areas through the removal of vegetation and the deposition of materials. Windblown paper, cardboard and plastic may fall in nearby riparian areas. Large flooding events may wash out portions of landfills and carry trash and refuse materials downstream.

Management

Environmental concerns have mandated changes in the construction and management of landfills. Lining of sites, construction of protective dikes or berms and better overall covering and compaction are some of the practices used. Other management practices are listed in **Table 23.**

In the future, methods of reducing waste and recycling may significantly reduce the material in the waste system which will also reduce the need for new landfills.
New landfills facilities will not be allowed within one-half mile of a one hundred year floodplain that has one hundred year flows in excess of twenty-five thousand cubic feet per second (A.R.S. §49-767.).

Table 22. Effects of landfills on riparian areas.

EFFECTS ASSOCIATED WITH LANDFILLS	
DIRECT	**INDIRECT**
Removal of riparian vegetation	Habitat alteration Increase in water temperature Decrease in oxygen content in water Change in pH of water Increase sediments
Soil disturbance	Increase sediment Alters channel material Alters channel geometry Degrades aquatic habitat Downstream channel changes
Increase contaminants leachate to groundwater leachate to surface water	Increase nutrients Increase sediments Increase pathogens Increase pesticides Increase petroleum products Increase volatile organic compounds Increase metals Degrades aquatic habitat Decline/death of riparian vegetation Threat to human health Changes pH of water and soils
Removes upland vegetation	Increase runoff, erosion Increases sediments

Sources: USEPA, 1993; ADEQ, 1992

Table 23. Protective management practices for landfill activities.

RIPARIAN AREAS PROTECTIVE MANAGEMENT PRACTICES for LANDFILLS
• Building facilities outside of riparian areas
• Rework landfills to remove contaminated materials
• Impervious liners/leachate collection
• Surface drainage controls
• Use DRASTIC maps for groundwater protection
Sources: USEPA, 1993

Wastewater Treatment Facilities

Description

The Arizona Department of Environmental Quality currently is tracking approximately 870 sewage treatment facilities of various sizes, types and ownership (ADEQ, 1993).

Wastewater treatment facilities vary substantially in their purpose, size and potential impacts. The simplest facility is a conventional on-site septic system with a leach field to handle waste from a single household. This system treats sanitary waste generated in the home, and disposes of the treated waste (from the septic tank) by means of a leach field (soil disposal). The leach field itself often provides additional treatment of the sewage. Modifications to these systems typically involve innovative disposal alternatives. These systems have a potential for polluting groundwater which will increase with the number and density of residences in the community.

Larger wastewater treatment facilities treat industrial and municipal sewage. Industrial treatment can differ significantly from the treatment that is required for municipal domestic sewage. Industrial waste will often be treated using mechanical or chemical processes where domestic sewage will be treated primarily with biological processes. Industrial waste will usually include chemical or metallic pollutants whereas domestic sewage will contain organic material and pathogens. Larger municipal wastewater treatment facilities regulate industrial dischargers through imposition of pretreatment requirements.

Most municipal wastewater treatment plants traditionally discharge treated effluent into surface waters. With increasing limits on discharge of pollutants to surface waters, however, treatment entities are turning more and more to other discharge options such as groundwater recharge and reuse such as for irrigation.

Lowland sites are often chosen for municipal wastewater treatment facilities because it is more efficient to allow the wastewater to flow under the force of gravity rather than forcing an uphill flow by pumping. As a result of this lower site preference, many of these activities are found near areas with riparian vegetation or in areas which once had riparian vegetation. However, the location and operation of sewage treatment plants are not dependent on the existence of riparian resources such as wildlife or the presence of rare plant species.

Effects

The direct effect on riparian areas is often only a local and continuous disturbance in the actual vicinity of the facility. Wastewater treatment facilities influence riparian areas as presented in **Table 24**. One of the most profound effects of wastewater treatment discharge is the increase in flow for the receiving stream. This is typically the case where the potable water used by a community or industry is from a different source than the stream system receiving the effluent.

The treatment of sewage and corresponding discharge of treated effluent into streams can have some beneficial effect on downstream riparian areas.

Table 24. Effects of wastewater treatment on riparian areas.

EFFECTS ASSOCIATED WITH WASTEWATER TREATMENT	
DIRECT	**INDIRECT**
Removal of riparian vegetation	Habitat alteration Increase in water temperature Decrease in oxygen content in water Change in pH of water Increase sediments
Soil disturbance	Increase sediment Alter channel material Alter channel geometry Degrade aquatic habitat
Alter streamflow - discharges	Increase streamflow Alter channel geometry Increase/decrease riparian vegetation
Discharge of pollutants to stream	Increase nutrients Degrade aquatic habitats Improve riparian vegetation vigor Decrease in oxygen content in water Increase pathogens Increase pesticides Increase petroleum products Increase volatile organic compounds Increase metals Threaten human health Change pH of water and soils
Remove upland vegetation	Soil disturbance Increase runoff / erosion

Sources: USEPA, 1993; ADEQ, 1992.

The addition of the treated and discharged water has allowed for a resurgence of riparian vegetation and wildlife in some cases.

The increase of riparian habitat replaces riparian areas that were otherwise lost or affected by human activities. These areas fulfill many of the functions of prior natural riparian areas which may have been found naturally at the sites.

The quality of these riparian areas has not been effectively evaluated. The discharged water may contain large amounts of nutrients that were not removed in the treatment process. These nutrients can increase plant growth. However, this can allow trees and vegetation to grow too quickly leaving them in a weak condition which makes them susceptible to diseases and insects. Other issues include the possibility of low levels of dissolved oxygen in the water which affects aquatic insect and animal species. Overall species diversity may be lower than in a similar natural riparian area.

Wastewater treatment discharges can affect stream water quality either directly or indirectly. Discharges into the stream will directly introduce pollutants. Discharges to groundwater recharge facilities may indirectly introduce the pollutants through aquifers that discharge into the streams.

Discharged nutrients can lead to aquatic habitat degradation through promotion of algal growth. High concentrations of organic matter in the effluent creates additional biological oxygen demand in the receiving stream which can reduce available oxygen for use by aquatic species. Other pollutants in the effluent can also detrimentally impact aquatic populations.

The main impact of on-site (e.g., septic) facilities on riparian areas is water quality related. Harmful chemicals (in larger commercial systems) or nutrients are often found in the effluent waters leaving leach fields. These materials can find their way into groundwater and eventually reach surface waters of riparian areas. The presence of pollutants affects both riparian plants and animals. Human health also is threatened by contact with contaminants through activities such as boating, fishing, and swimming.

Management

The opportunities for managing impacts from wastewater treatment facilities are rather limited. Some of these measures are presented in **Table 25**. Impacts are most effectively managed through siting facilities such that direct impacts to riparian areas are minimized. Further protection could be provided through increased water treatment and flow equalization.

Creation of artificial marshes to filter and cleanse wastewater effluent have been proposed. These facilities would be out of the flood prone areas. Plants, animals and bacteria would be introduced into the system to biologically treat the wastewater before it was discharged into the riparian area. This would solve some of the water quality problems. In other situations, the water would be allowed to stand in the open where it will eventually evaporate. In this case, riparian areas would not benefit from wastewater processing.

Large areas of riparian vegetation and animal habitat created and supported by treated effluent discharges can be found on the Salt, Gila, and Santa Cruz rivers. Development of effluent dominated riparian areas is controversial due to the scarcity of water in Arizona and questions surrounding the quality of the discharge. The treated water maintaining these riparian areas may be eventually diverted for water reuse purposes such as agriculture or to be used by other activities.

Table 25. Protective management practices for wastewater treatment activities.

RIPARIAN AREAS PROTECTIVE MANAGEMENT PRACTICES FOR WASTEWATER TREATMENT FACILITIES
• Siting facilities outside of riparian areas
• Improve water treatment to limit nutrients
• Maintain discharges from facility to streams
Sources: USEPA, 1993, ADEQ, 1992.

Mines and Metallurgical

Description

Arizona is fortunate to have a diversity of geologic features and mineral districts rich in lead, zinc, molybdenum, pyrite, gold, silver, and copper. With over 102 mines active, excluding sand and gravel operations, Arizona ranks as the nation's leading mineral producer and first in mined gemstone production (Phillips et al., 1993).

Mining and metallurgical operations depend upon mineral resources found across the state, occasionally in or near riparian areas. The density of mining is greatest within mineral districts that create a dispersed pattern crossing the center of the State. Deposits of energy producing raw materials like coal and uranium are found in the northern part of the State. The extraction of these materials from the earth and the potential for great wealth from these riches attracted many people, explorers, prospectors, merchants and settlers. The construction of towns and transportation networks such as roads and rail lines to service the mines opened up many economic opportunities.

Mining and metallurgical operations involve numerous steps. Some of the steps can influence riparian areas. In the exploration and prospecting stages of mining there is a search for mineral deposits. In the State, many potential mining sites have been identified within the known mineral districts. Identification of ore bodies that are of economical quality means assaying of an ore sample. Determination of economic feasibility of mining the site involves the estimation of the overall size of the deposit and frequently an ecological assessment. Permits and licenses are required before operations can begin.

Effects

The effects that mining has on riparian areas are primarily in the local vicinity of the operations. The intensity of those effects is very high in some locales. The effects are the removal of plants and ore from the mineralized areas and the deposition of overburden materials. Large amounts of overburden, waste rock, and tailings have been produced and deposited altering drainage patterns in the watershed by impounding or diverting surface waters. Large storm events have caused tailing ponds to breach spilling tailings into drainages. Several copper mining operations use in-situ leaching with sulfuric acid. Groundwater near the mining and milling sites has experienced increased concentrations of sulfate as well as total dissolved solids (ADEQ, 1988). The effects that mining and metallurgical operations have on riparian areas are listed in **Table 26**.

Mines are moderately dependent upon the water resource component of riparian areas. Water is used during processing. Toxic contamination can occur from spills of processing chemicals, sulfates, and heavy metals. Chemicals can leach into aquifers from tailings piles. The acidity of the water can increase from the chemicals. The contaminated waters may eventually return to the surface by seepage or pumping for other uses such as irrigation or drinking water. These contaminants directly affect human health or riparian areas. In some instances, especially hydraulic placer mining, the activity has been in riparian areas; but overall, the activity is not totally dependent on streams or rivers for its existence.

Table 26. Effects of mining and metallurgical operations on riparian areas.

EFFECTS ASSOCIATED WITH MINING AND METALLURGICAL OPERATIONS	
DIRECT	**INDIRECT**
Alter water drainage in watershed	Remove/divert surface water Decline/death of riparian vegetation Degrade aquatic habitat
Alter channel geometry	Decline/Death of riparian vegetation Decrease aquatic habitat
Increase contamination downstream	Increase heavy metals surface water groundwater Increase sediment Increase nutrients
Vegetation removal	Habitat alteration Increase in water temperature Decrease in oxygen content in water Change in pH of water Increase sediments
Discharge to stream	Increase contaminants in channel
Soil disturbance	Increase sediments in channel

Sources: USEPA, 1993; ADEQ, 1988; Marcus, 1983.

Controlling and using water in mines is important to these activities. One of the problems encountered by some mines in Arizona is the leaking of underground water into the shafts, drifts, and pits. This was solved by pumping the water to the surface. The pumped water or surface water is sometimes used in the metallurgical smelting or refining processes. The water, after use, is often contained in large settling ponds where sediments are deposited. Eventually, the water evaporates or infiltrates, leaving behind previously dissolved chemical components. These chemical components may make the soils unsuitable for vegetation growth. At other times, groundwater removed from large dewatering activities may not be used for processing. The water is discharged directly into a drainage possibly supporting riparian areas. Dewatering of aquifers from these processes also might affect riparian areas as the water table drops below the plant root zone causing plant stress or death.

The filling of ephemeral streams with rock waste has been a cause of sedimentation in downstream intermittent and perennial streams. Rain water dissolves chemicals from the abandoned disturbed areas and runoff then carries it to waterways. Contamination of the air from wind blown materials blown off disturbed areas or from smelter emissions can affect plants downstream, both on the watersheds and in the riparian areas themselves.

Arizona has many abandoned mines, unused rock overburden, product piles and tailing piles. These areas have the potential to affect water quality. Other effects have included the removal of water from surface streams for ore processing and the cutting of timber from riparian zones and other areas. This timber was used for fuel and for the construction of shoring of mine tunnels and shafts.

Management

Most human economic activities are somehow dependent on minerals such as copper and gold. Mining locations are totally dependent upon the natural distribution of the earth's raw materials. Often, these necessary and valuable deposits are located in the vicinity of riparian areas. Normal operations must unavoidably disturb or destroy those areas to reach the sought after deposit. Managing those operations to reduce the effects is critical for nearby riparian areas (**Table 27**).

There are many laws and regulations which influence mining and metallurgical operations. These laws and regulations have been established to protect the safety and health of miners and to protect the environment. Environmental assessments (EAs) and environmental impact statements (EISs) may be necessary to meet the National Environmental Policy Act (NEPA) activity planning requirements. Discharges of water from the sites require a National Pollution Discharge Elimination System (NPDES) permit. Disturbance of the stream channel can require a Section 404 Clean Water Act permit. Also, if there is a possibility of groundwater contamination, an Arizona State Aquifer Protection Permit (APP) that requires Best Available Demonstrated Control Technology (BADCT) measures is required. Of course, voluntary use of best management practices and careful on-site operation management can help reduce effects on riparian areas.

Unavoidable destruction may occur if the activity cannot be relocated. The preference is for on-site mitigation, however off-site mitigation may occur to enhance or protect riparian areas found elsewhere.

Restoration and reclamation of old or abandoned sites would likely enhance riparian habitat in that area and minimize pollution problems. This option is often expensive. Although the sites can be restored to some level, the original systems will never be able to be replaced. Additional opportunities exist for mining and metallurgical operations' to cooperate in the process of protecting in stream flow rights. This process would eventually allow for the continued presence of water in existing riparian areas.

Table 27. Protective management practices for mining and metallurgical operations.

RIPARIAN AREAS PROTECTIVE MANAGEMENT PRACTICES FOR MINING AND METALLURGICAL OPERATIONS

- Avoidance of riparian areas
- Minimization of impacts; control runoff and discharges to groundwater
- Restoration of abandoned mines in riparian areas

Conclusions

This report evaluated various activities and the effects they have on riparian areas. The effects of activities are complex and variable. This is primarily due to the fact that each activity is unique in its frequency, intensity, duration, individual site size and statewide spatial extent.

Summary of effects

A matrix summarizing the direct effects of activities as discussed in the report is presented in **Table 28**. The effects are grouped according to hydrologic, channel and floodplain, biotic, and water quality functions. Some effects occur for all or most of the activities evaluated. These effects, in decreasing order of frequency, are: the removal of riparian vegetation, soil disturbance in the floodplain, alteration of the channel geometry, increase contaminants in the water and removal of upland vegetation. It is interesting to note that the hydrologic effects are scattered with no particular effect having a significantly higher frequency than another.

Other observations regarding this evaluation are as follows:

- Water is the key component of riparian areas for both intermittent and perennial streams. Activities which **influence runoff** such as grazing, timber harvesting, and urban development, **control flows** such as dams and channelization, or **use diverted water** such as agriculture and urban development, effect riparian areas by limiting surface and subsurface water flow.

- Activities that typically occur within stream channels and change the channel geometry or disturb the soil, have a higher potential of causing direct effects. These activities are sand and gravel extraction, road and bridge construction, dam and reservoir construction and operation, and channelization and bank stabilization. Dam construction has had the most profound effect on streamflow patterns.

- Activities which remove riparian vegetation alter the terrestrial and aquatic habitat. However, if streamflow has not been altered, vegetation has a high probability to recover. This resilience is a natural component of the dynamic environment found in riparian areas.

- The intensity of any one activity often varies from site to site. Depending on this intensity, the results range from little change to a complete alteration of the riparian area. The effects of activities are found not only in the immediate proximity to the sites, but can extend far downstream (e.g dam and reservoir construction, wetland drainage).

Table 28. Summary of direct effects activities have in riparian areas.

Direct Effects	Timber Harvesting	Agricultural Land Clearing	Recreation Use & Development	Commercial, Residential, Industrial Development	Road & Bridge Construction	Dams & Reservoir Construction/Operation	Channelization / Bank Stabilization	Sand & Gravel Extraction	Wetland Drainage	Grazing	Landfill Facilities	Wastewater Treatment Facilities	Mining & Metallurgical Operations
HYDROLOGY													
Remove / divert water		X				X		X	X				
Lowers groundwater table								X					
Obstruct streamflow					X	X		X					
Discharge to stream				X								X	X
Increase runoff, erosion, water yield	X							X					
Alter water drainage				X	X								X
CHANNEL/FLOODPLAIN													
Soil disturbance		X	X	X	X			X		X	X	X	X
Impervious surface/soil compaction			X	X	X		X						
Increase stability of floodplain						X	X		X				
Alter channel geometry			X		X	X	X	X	X	X			X
Alter channel materials					X	X	X	X		X			
Line channel							X						
BIOTIC													
Remove riparian vegetation	X	X	X	X	X	X	X	X	X	X	X	X	X
Remove upland vegetation	X	X								X	X	X	
Reduced effects of cattle						X							
Decrease wildlife			X		X								
Increase wildlife								X					
WATER QUALITY													
Increase fecal material										X		X	
Increase contaminants into water	X	X	X	X	X		X	X		X	X	X	X

■ The degree of effects vary over time and space and the effects can be cumulative. An example of these cumulative effects on the Salt River through Phoenix are: agricultural land clearing (removed vegetation); dam and reservoir construction (removed water); road and bridge construction, sand and gravel operations and channelization (modified the channel); commercial, residential and industrial land uses (covered soil surface of the floodplain); and landfills and sewage treatment facilities (sited on floodplains). The final result is a totally modified riparian area.

Activities can be grouped according to their site preference, which is dependent on resources and operation or function. **Table 29** presents the site preference for the activities. Activities that occur directly in or over riparian areas can significantly affect water flows or channel and floodplain structure in a direct manner. Such activities as dams, channelization and bank stabilization, and bridges always occur along some type of drainage or channel. Other activities such as sand and gravel extraction can usually be found in close proximity to drainages or on the surrounding lowlands because that is where alluvial materials are

Table 29. Site preference of activities

RIPARIAN AREA EVALUATION	
ACTIVITY	**SITE PREFERENCE**
Dams Wetland drainage Channelization and bank stabilization Bridges	Directly in / over riparian or wetland areas
Sand and Gravel Operations Irrigated Agriculture Wastewater Treatment Facilities	Close proximity to channel or riparian areas
Grazing Commercial, residential, industrial development Roads and highways	Riparian areas and uplands
Timber Harvesting	Uplands
Recreation Landfills Mining	Multiple preferences or no preferences

deposited. Wastewater treatment facilities occur in lowlands because it is logistically easier to allow water to run downhill. Grazing, road building and development occurs in both lowland and upland areas, but there is tendency to occur more often on the lowland areas. Activities such as timber harvesting are often found in the uplands for reasons such as type and quality of trees.

Some activities can occur in many places or are dependent upon other factors. Recreation can occur across the landscape. Many factors determine locations of landfills including economics, politics and environmental impact. Mining and metallurgical operations are dependent upon the natural occurrence of ore bodies and other economic considerations such as the costs of transportation.

Proposed management practices

The relationship between the effects of an activity and the activity's proximity to a riparian area is illustrated in **Figure 3**. The vertical axis represents the total intensity of effects. The horizontal axis represents how close the activity is to a riparian area. The number of effects or intensity is greater the closer an activity is to a riparian area. As the distance from the riparian area increases, the effects decrease.

The relationship of two types of effects, direct and indirect, relative to an activity's proximity to a riparian area is illustrated in **Figure 4**. Activities located close to riparian areas have more direct effects on the area. An activity located further from a riparian area may not have as many direct effects but may have indirect effects. Direct and indirect effects can impact riparian areas.

Four management strategies used to protect riparian areas are illustrated in **Figure 5**. They are avoidance, restrict activities, technological controls, and BMPs. For those activities having the greatest number and intensity of effects directly in or near riparian areas, avoidance of riparian areas may be the most effective management tool; particularly for high quality riparian areas. Restrictions of activities (such as controlled access) may be used for those activities which may directly affect riparian areas; particularly those of lesser quality. Reduction of indirect effects using technological or other management tools may be more appropriate for activities which are farther away from riparian areas. For those activities which occur primarily on the upland, the use of BMPs can help reduce the indirect effects. Of course, BMPs, technological controls, restriction of activity and avoidance of riparian areas can be used in any combination by all activities to protect riparian areas.

Direct disruption of water supply or alteration of the channel and floodplain are most effectively managed by proper siting. Further, activities that physically effect either the water supply to a riparian area, the physical setting of the riparian area, or the riparian vegetation would probably consider avoidance or minimization of impacts to high value riparian areas. For activities in lower value riparian areas, minimization or compensation mitigation may be a more appropriate strategy.

Figure 3. Effects of activities versus the activities' proximity to riparian areas.

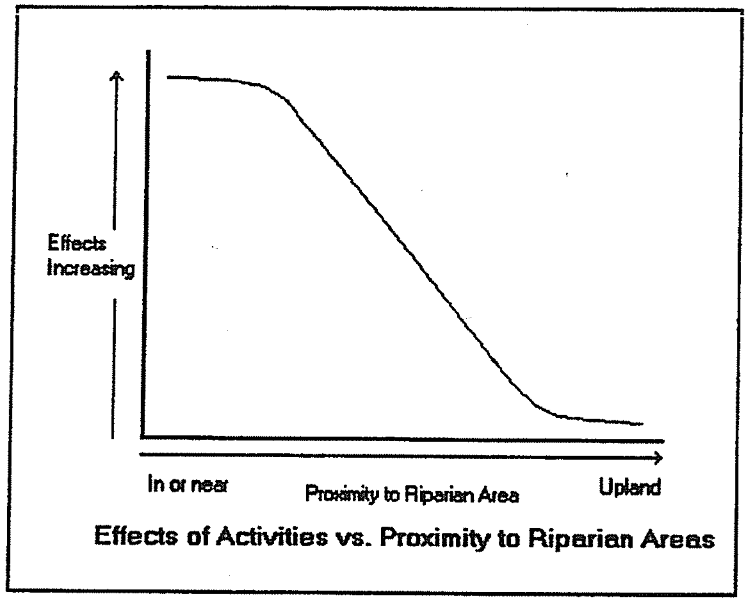


Figure 4. Types of effects of activities in relation to the proximity to riparian areas.

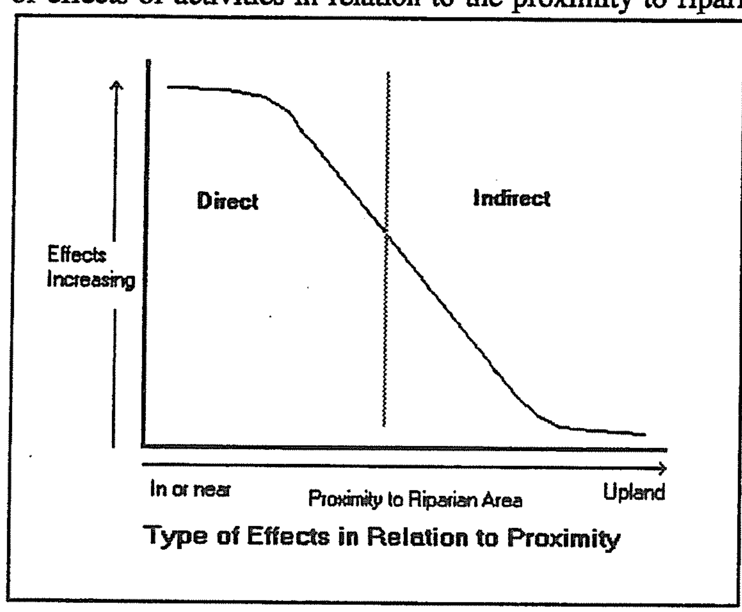
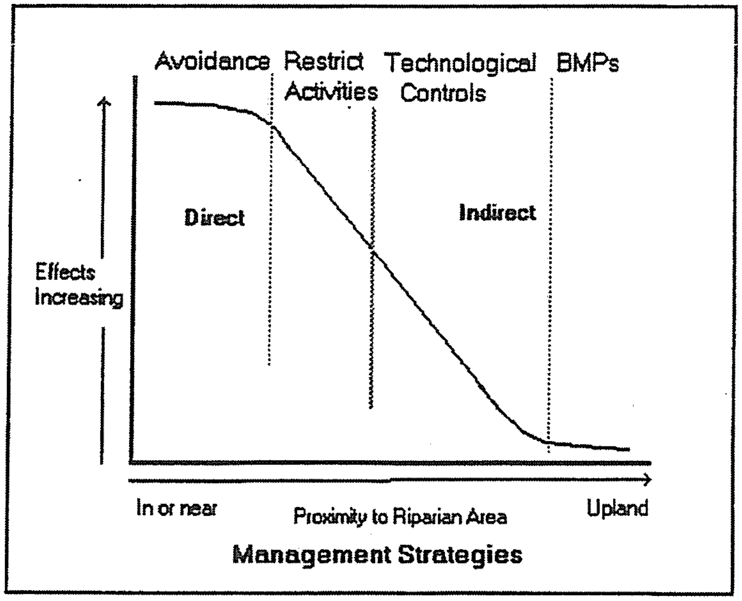


Figure 5. Management strategies to protect riparian areas.



For activities that do not directly effect the physical setting of the riparian area, avoidance may not be an appropriate or reasonable strategy. Minimization of effects is more likely the most effective strategy. For example, a metal mine located in an upland area that drains to ariparian area may indirectly effect the groundwater and surface water quality supporting the riparian area. This potential risk could be minimized through water treatment or runoff containment.

This report is the first in a series of reports describing various aspects of riparian areas. The effects of certain activities on riparian areas and strategies to manage these areas is presented. The compilation of information provided in this report and in forth coming reports from Arizona Game and Fish Department and Arizona Department of Water Resources, will provide a framework on which a reasonable strategy for riparian protection will be developed.

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